INDIAN TEA ASSOCIATION.

REPORT

OF THE

COMMISSION OF ENQUIRY

ON THE

SCIENTIFIC DEPARTMENT,

1935–36.

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THE CHAIRMAN,

INDIAN TEA ASSOCIATION,

LONDON.

Dear Sir,

We, the members of the Commission, appointed by your Association to report on its Scientific Department, beg to send you herewith our Report.

We have written for the varied readers represented by the tea industry, avoiding scientific terms as far as possible. This has lengthened the Report by explanations which for scientific readers will be superfluous.

Our investigations, beginning with discussions and the study of scientific reports at home, have been prolonged over seven months. They have included visits to Ceylon and Java and a period of ten weeks in India, divided between tours in the tea districts, meetings in Calcutta and a stay at Tocklai.

We have many kindnesses to acknowledge. Our first step must be to speak of our gratitude to the tea industries of Ceylon and Java and to the Governing Bodies and Staffs of their research stations. To most generous social and scientific hospitality they added unhampered freedom of access to information of all kinds.

On tour in India, for several weeks, while constantly enjoying the technical assistance of the planting community, we also depended wholly on them for sustenance. To our many hosts and hostesses, of whom we take away very grateful recollections, we make our warmest acknowledgments.

Mr. D. C. Stewart-Smith has acted as Secretary to the Commission and Mr. R. J. LeFaucheur as Stenographer and Typist. We thank them both.

Yours faithfully,

F. L. Engledow.

Jas. Insch.

J. M. Kilburn.

R. B. Lagden.

3rd March, 1936.

INDIAN TEA ASSOCIATION.

Report of the Commission of Enquiry on the Scientific Department, 1935-36.

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INDIAN TEA ASSOCIATION.

Report of the Commission of Enquiry on the Scientific Department, 1936.

SECTION I.

INTRODUCTION.

1. The terms of reference of the Commission were :—

> "To make a full enquiry into the constitution, administration and working of the Tocklai Experimental Station and to indicate any changes that may be desirable in
>
> (*a*). the constitution and governance;
>
> (*b*). the orientation of the research work of the Station."

In a circular (A. 59, dated the 12th September, 1935) to all its members, the Indian Tea Association (London) specified some of the matters in which enquiry should be made in the following words :—

> "It is desired to ascertain in the interests of the industry, whether the work which is in progress is best calculated to produce results which will be of commercial benefit to the industry when applied. Also whether the organisation of the present Station calls for any alteration and generally whether results are likely to be commensurate with the expenditure directed to research.
>
> It is also felt that, if possible, there should be international co-operation in research work, a full exchange of views and results and an endeavour to avoid overlapping in the activities of the different scientific stations maintained by producers in North and South India, Ceylon and the Netherlands East Indies."

The members appointed to the Commission were :—

Prof. F. L. Engledow, C.M.G., M.A., B.SC., Draper's Professor of Agriculture, Cambridge.

Mr. James Insch, *Commercial Member.*

Mr. J. M. Kilburn, *Planting Member.*

Mr. R. B. Lagden, M.C., (Nominated by the Indian Tea Association, Calcutta).

Mr. D. C. Stewart-Smith was appointed Secretary and Mr. R. J. LeFaucheur has acted as Stenographer.

With circular A. 59 there was also sent to every member of the Indian Tea Association (London) the following questionnaire :—

(1). What in your opinion are the major problems of the industry under the headings?

(*a*). Production; (*b*). Manufacture.

(2). Have you any criticism to offer of the work of Tocklai in the past under the following headings?

(*a*). Scientific Research.
(*b*). Advisory Work.
(*c*). Practical Planting.
(*d*). Practical Manufacture.

(3). Have you any suggestions to make regarding the future work at Tocklai whereby greater assistance would be given to the planter?

Of 24 Agency Houses which received the questionnaire, 4 sent replies; for Tea Companies the numbers were 33 and 6; for Tea Brokers 14 and 3; for individual members 46 and 2. In addition the Commission received verbal evidence from 14 witnesses in London, of whom 3 were tasters. The questionnaire was also sent to all its members by the Indian Tea Association

Calcutta). In the circular (No. 48, dated the 27th August, 935) of which it formed part it was explained that representa- ve associations of producers had been separately invited to send eplies and to give the names of witnesses who would be willing o meet the Commission; Agency Houses were asked to submit comprehensive note of the views held by all the Companies and states in their agency. Twenty replies were received from India nd the Commission gratefully acknowledge the care and clear- ess of the replies to the questionnaire and the kindness of the ndian Tea Association (Calcutta) and all others concerned in aving the replies from India made available for one of its home nembers before he sailed. A summary of the replies received rom London and from India is given in Appendix I to this Report and a list of witnesses and respondents and of estates isited in Appendix II.

During the six months before sailing, the home members of the Commission were enabled, through kindness now warmly cknowledged, to discuss, at length, various aspects of the tea ndustry of India and of Ceylon in relation to research work.

One of them visited Ceylon and Java where the courtesy and complete freedom of access he received gave him an acquaintance with the problems of tea and their scientific treatment which has done much to assist the Commission in its work.

Two representatives from Southern India also met the Com- mission in Calcutta and discussed with them, at length, the work of their own Research Station and the question of co-operation in research among tea producing countries.

The Principles Followed.

2. The Commission commenced its work by deciding on the principles in the light of which it should take up its terms of reference. It was guided in part by consideration of the work and circumstances of Tocklai. Further it took into account the experience of a number of other stations devoted to research on

crop products. The principles which, with frequent re-examination, have been employed all through the Commission's work are :—

(*i*). The purpose of the Tocklai Station is twofold; first—to employ the sciences for the economic betterment of the tea growing industry; next—by appropriate advisory work to help planters to use fully all the assistance the sciences can offer.

(*ii*). The constitution and administration of a research station should be primarily designed to promote the scientific work of the station and must, therefore, sub-serve it.

(*iii*). Policy in applied research must be determined by the economic circumstances of the industry concerned. It must consequently take the form of attacking the chief problems of the industry.

(*iv*). It is the duty of the research station to formulate these problems for itself keeping, for that purpose, in very close touch with all sections of the industry.

(*v*). As the number of problems in an industry such as tea production is unlimited, those to be studied must be very carefully selected. They must be clear and tangible and not as a whole beyond the research station's resources. The transient difficulty must be distinguished from the enduring problem.

(*vi*). In attacking a problem of industry the relevant economic and practical circumstances should first be fully studied. The scientific problems involved in the industrial problem should then be identified.

(*vii*). In the next stage, which is to study these component scientific problems, the research worker must have the full freedom which general experience shows to be essential for all original investigation. But he should, at all times, remember that the one aim of his work is to advance the industry.

(*viii*). For success in translating experimental results into commercial practice, action on two sides is required. The investigator must fully work out the practical implications of his results and test their validity under the varying conditions of the industry. And for their part, practical exponents must recognise that the final test of the practical value of any new method can be obtained only by widely arranged practical trial, so that the research worker cannot always, in the early stages of a possible new development, be in a position to speak with complete certainty. And in the broader field of their terms of reference the Commission adhere to the further principle :—

(*ix*). That in so far as it is practicable, it is in the ultimate interest of all tea producing countries to join together in advancing knowledge of the tea plant and of tea making.

There can be no rules for research policy and the choice of principles must be determined by the circumstances of the industry and the research organisation concerned. For instance, in illustration of this point, the Empire Cotton Growing Corporation recently, in inviting applications for a senior vacancy at its central research station in Trinidad, spoke thus of its policy in research :—

"Broadly, the objective of the Station (in Trinidad) is to obtain knowledge of the fundamental properties of

the cotton plant and lint. It is thus able to take up investigations which are beyond the scope of the Agricultural Departments and of the Cotton Stations in cotton growing countries. The Corporation does not closely define the policy to be adopted by the Trinidad Station in working towards the broad objective stated above, *viz.*, to obtain knowledge of the fundamental properties of the cotton plant and lint. It leaves to its staff the freedom in choosing lines and methods of investigations which such an objective necessitates. At the same time the Corporation feels that the work of the station should be so directed as to conform with the Corporation's inherent obligations to promote the interests of cotton growing in the Empire. Thus the ultimate aim in seeking fundamental knowledge is the creation of new methods and the improvement of existing ones in plant breeding and in all the aspects of cotton growing."

Here is an instance of a central station for fundamental research, more immediate and local investigations being in the hands of stations in the various British cotton territories. The circumstances are very different from these of Tocklai which, single-handed, serves all the scientific needs of North-East India. Some of the advantages of a central station might, we feel, be secured to Tocklai by collaboration in research with the other tea research stations.

SECTION II.

THE ECONOMIC SITUATION OF TEA AND ITS BEARING ON RESEARCH.

3. The major features of a programme in research cannot be changed rapidly. On the other hand, the need of the moment may, in industry itself, change swiftly and often. It therefore follows that in directing research policy to the problems of industry, great care must be used so that the problems studied may be commensurate with the time and effort their solution occupies. Substantial study is only justified on major problems of an enduring kind. In considering the bearings of the economic situation on research, it is only with the major aspects that we are concerned. Detailed study of research is taken up in later sections. Our considerations necessarily fall under the headings of production and consumption.

Tea Consumption.

4. In present circumstances consumption lies at the heart of tea economics. What is being done by propaganda to encourage a greater use of tea is well-known and is outside our reference. We think it desirable, however, to speak of a possible counter-influence in the form of hostile propaganda. Dogmatic statements concerning human health, even though supported by no more than fantastic theoretical evidence, are apt to lay hold of the public mind. The harmfulness (and wholesomeness) of everything in common use (including tea) has been repeatedly "proved" and the resurgence of a wave of fancy may, at any time, prove damaging to any article of diet. It seems, therefore, worthwhile to be prepared in advance by obtaining experimental evidence of a kind which scientific and medical opinion would accept. We have seen a certain amount of published experimental work bearing on the relation between tea and health but we think a more substantial and carefully planned study of the question should be made. In the questionnaire replies, consumption was only once referred to, the suggestion being that the making of green tea for Indian and other Eastern markets should be investigated.

5. That quality and consumption are related is obvious, but in exactly what way is by no means clear. The nature of this relationship is, however, of great economic importance and we feel the industry should have it constantly under review.

6. There must be recognised now, in connection with a vast number of valuable products, what may be called the "principle of displacement". For many purposes, metal has displaced wood; for clothing, wool and artificial silk now increasingly displace cotton; cotton is now used where some years ago leather might have been employed and so on. For a long time such displacements came about slowly and almost without planning. But now, in industry, displacement is a working principle for which material is furnished by active research. It would be inappropriate to discuss here the application of the principle to tea but we feel that consideration should be given to it by some suitable organisation whose general duty it should be to study the problem of consumption and to undertake consumption research. This research would include a vigilant study of any changes in the public taste concerning tea at home and abroad. In our view the London Advisory Committee, for which proposals are made in Section X, in conjunction with the International Tea Market Expansion Board, might be responsible for this work.

Tea Production.

7. With output restricted, the prime production problem in North-East India, as a whole, is how to produce the permitted total amount of tea at the least possible cost and to obtain for it the highest possible average price per pound. In treating of the area as a whole it is necessary, of course, to take note of the fact that some estates show much greater efficiency than others. Now while it is for the owners of the least efficient estates to decide upon their line of action, those responsible for research policy cannot be unaffected by the differences in efficiency on different estates, for from them arise corresponding differences in the problems requiring solution. We take the view that neither in

its research nor its advisory work should the Scientific Department be expected to make special efforts out of proportion to their importance in aid of a small number of cases in which exceptionally low efficiency is achieved. For the individual estate, as for the area as a whole, the prime requirement is to produce its permitted amount at the minimum cost and at maximum value per pound. The components of this requirement are yield per acre, labour costs and quality (in the sense of selling price per pound).

Tea Growing: Present.

8. The influence of output restriction on policy in tea growing is everywhere apparent. It has directed much attention to the idea of obtaining the permitted output of the estate from only a part of the total area under tea by intensive cultivation, the remainder of the area being "rested". Several problems arise from this plan and among them; how "resting" should be managed; whether labour costs can be lessened on the intensively worked area; whether gradual replanting with more suitable jat would be profitable.

9. Upon production costs, too, the fact of restriction bears with special interest and many of our witnesses have suggested that the possibility of reducing labour charges should be looked into. It may be said that production costs depend first upon the production methods employed and next on the efficiency with which they are employed. In many European countries, in North America and some other countries, surveys of cost of production and of management efficiency in agriculture have been made. It cannot be doubted that these, when on an analytical basis and properly arranged, serve two highly important purposes. They give a clear view of the industry or an area as a whole and without such a view it is hard to frame any general policy for the whole. Again they make it possible for any one farm or estate to compare itself with the average or, for instance, the best 10% of all the estates (the identity of estates is not disclosed in publishing the result, but is not, of course, needed in any such comparisons). Various bases of comparison can be

adopted, for instance; gross output of produce for every £100 spent on labour. Farms or estates are grouped together in such surveys on the basis of soil type, size, etc.

10. The tea industry is so circumstanced that surveys of this nature could be made from the records which each garden keeps as a part of its routine. And it is, we know, the regular practice of Agency Houses to appraise efficiency of estate working. Whether a special analysis of all the available data would be worth while must be left to the judgment of the Agencies.

Tea Growing: Future.

11. So great is the significance of restriction that it is difficult for producers to think beyond the present. It is essential, however, to attend to possible future circumstances of which one may be the removal of restriction with or without a change in world tea consumption. The future is indeed uncertain, but general inferences may be drawn. Thus, clearly, it is wise to conserve the condition of the soil and the development and health of the tea bushes, so that if the chance of increasing output comes, it may be taken. To keep a firm hold on diseases in the tea areas at large thus seems economically sound and for this, not only research, but also unremitting use of established preventive measures are required.

12. Conservation of soil and of plant health are peculiarly interesting problems with perennial crops like tea planted on land which, a relatively short time ago, was virgin. Slow changes, indicating long but perhaps vitally important effects, must be expected. Humus content, it may be surmised, will become of cardinal importance. For this reason we feel that in research on manuring something more than the immediate question—"inorganic *versus* organic" manure—is at issue. Humus content over long periods must be studied and the various methods of supplying humus should be searchingly examined.

13. Consideration of slow, cumulative, soil changes brings up the question of the "life" of tea. Through severe general deterioration of the tea bushes or because new and greatly

improved jats are produced, a wholesale replanting might become necessary (as distinct from gradual bush replacement). Could this be effected profitably on land which had carried tea for fifty to seventy years and what would be the best methods of replanting? Many questions of this kind arise and we feel that the general issue of the "life" of tea in North-East India should be studied.

14. It does not seem to us outside the range of this general economic survey to mention the circumstance that tea, like rubber, coffee, cacao and in places even wheat is often grown alone, *i.e.*, on single crop estates. How disastrously disease or economic circumstances have at times dealt with single crop or single annual product enterprises in non-tropical countries is well-known. North-East India, unlike some other tea areas has plenty of unplanted land on its tea estates. Whether other profitable crops could be found for this and whether by raising them the labour distribution throughout the year would be helped or hindered are questions into which we cannot enter. We feel, however, that this situation must be reckoned as one of the economic circumstances of the industry. If a crop could be found which did well on tea soils in general and yet was of a kind not to compete with tea as a commodity, fears for the future of tea would begin to melt away.

Research on Tea Growing.

15. Some hold that when an industry meets a difficult period, research work should be intensified; others that it should be reduced as a means of economising. Both these views are too general to be discussed here but we wish to explain our attitude to the more specific suggestion that production being strictly limited, profit is governed by quality and, therefore, research on tea growing should be given up except in so far as quality is concerned.

16. Our general answer to this suggestion is that sudden changes in research policy are often dangerous. Speaking more specifically we think it important to remember that of the capital

sunk in a tea estate about one half is estimated to be in planting, and development while the bushes are growing (as distinct from tea making) is also responsible for a big proportion of recurrent production costs. Moreover, in rival products like coffee and cacao and in rival tea growing areas, research on the growing side is being steadily increased. Even China whose potentialities for tea export cannot be ignored, is making for tea research work the same comprehensive provision as for the other parts of her agriculture. Russia's great interest is also well-known. We recognise that the economic future of tea is still unpredictable and are therefore of the opinion that the wisest way of facing it is by gaining the completest possible knowledge of the tea bush. This means we favour a continuance of research on growing. But it may be expected to be easy for some years to produce all the tea which can be sold and planters in their evidence show a general satisfaction with existing methods. This leads us to suggest that research should now be largely directed to those matters which, like jat selection and vegetative propagation, though so far little known, are of great potential importance rather than to more immediate questions such as alternative orthodox methods of pruning.

17. At present, labour is "dearer" in North-East India than in some other tea countries and there is no reason to expect a change in this matter. Now when labour is costly it must be used with the highest possible efficiency. This, in some circumstances, *e.g.*, wheat growing in Australia, can be ensured by the use of machinery. In tea growing there seems, at present, no scope for machinery (save in transport) and no ready way in which labour efficiency can be much increased. It, therefore, appears of the highest importance for dear labour countries to take other kinds of measures to maintain their position in relation to competing countries. We believe that for North-East India the power to increase yield per acre without correspondingly increasing labour charges should be resolutely sought. And, further, this power is most likely to be obtained by improved jats. Improvement implies increased yielding capacity,

greater uniformity than in existing jats, and the provision of jats specially adapted to the various climatic and soil regions of North-East India.

Tea Quality.

18. Various opinions have been expressed to the Commission about the relative importance of yield per acre and quality as subjects for experimentation. One view is that yield is satisfactory and that quality alone needs study; another that it must be sought to increase yield without loss of quality; a third that simultaneous improvement in both must be aimed at. It has never been suggested to us that quality could be ignored if yield was sufficient, and in the 1933-1934 Annual Report of the Indian Tea Association (London) occur these words in connection with the possibility of increased consumption in India :—

> "It must be clear that if this is to depend on cheap tea it is not going to help us out of our difficulties."

19. Cheap tea here implies tea of low quality. The idea that the quality of North India tea in general should be raised must be examined in regard to both economics and scientific research. If all tea advances in quality, will all prices correspondingly advance and will consumption increase? Owning companies must answer this question according to their several circumstances. There is a further question—is it possible to limit the range of research on quality to certain classes of tea? For instance could the worst (say 15%) and the very best (say 10%) be disregarded and enquiry be limited to the still great problem of improving the remaining grades of quality? Some of our witnesses have suggested that the essence of the quality problem is in the rains tea and that this alone need be studied. In our recommendation concerning lines of research, we have carefully weighed questions of this kind.

Research on Quality.

20. All our enquiries and experiences have convinced us of the superlative importance of research on quality of tea. Tea, with

tobacco, is distinguished from most other great crops by the wide range and subtlety of its quality and by the important influence quality exercises on price. If the scientific endeavours of rival products or countries are an important consideration in the matter of growing, as above we have declared them to be, they count still more in the matter of quality. For with tea, coffee and similar substances, within somewhat narrow limits, quality determines not only price on sale, but possibility of sale. And, further, there is another aspect of quality besides its average level and that is uniformity. By ensuring uniformity one product has sometimes been able to oust a better. It cannot be doubted that on the market, uniformity is of very high importance : and yet, as evidence shows, certainty of control over manufacture and thus over uniformity of quality is one of the planter's greatest needs. This form of the problem of quality may be put in another way. For any one set of soil, altitude and climatic conditions, quality of the made tea is largely pre-determined before the leaf is plucked from the bush. It is possibly by this pre-determination that the general market reputation of the tea from the area concerned is primarily decided. The quality problem may, from this point of view, be stated as the problem of finding out how not to ruin quality in the factory as constantly and cheaply as possible. The influences of soil and climate may be said, from this point of view to create a special quality problem for every estate, *viz.*, what is the best quality of tea which the leaf of the estate is capable of producing or—and this is possibly the better way of stating the problem—what is the most profitable degree of quality to work for on any estate? On economic grounds then, research on quality is a salient requirement. No more obscure subject for research on crop products could, perhaps, be found. We conclude that the needs of the industry justify, and indeed dictate, a substantial outlay and a bold attitude in research on quality.

21. "Ignorance"—some of our witnesses have used this word—most truly defines the real problem of the industry in regard to manufacture. The nature and effects of the factors

chiefly influencing each process are very imperfectly known. If knowledge of these things can be supplied by research it will help the industry not only to do better in existing circumstances, but to meet fresh circumstances in the future, whatever they may be.

22. In paragraph 232 we express the opinion that the Scientific Department should prepare a programme of work based on a reasoned policy derived from the needs of the industry. We feel it no less necessary that the industry should, from time to time, examine its situation and formulate its policy. The business advantage of doing this, the industry must judge for itself. Our motive in suggesting it is to ensure to the Scientific Department that understanding of major policy which it needs in deciding on its programme of research. Questions like "single crop" policy or the general attitude to quality improvement illustrate matters which might be covered by a statement of major policy. It might, we think, appropriately be one of the duties of the London Advisory Committee (see Section X) to prepare the statement of policy in conjunction with the Indian Tea Association (Calcutta).

23. It has been our concern in this section to discuss the chief features of the tea industry in North-East India as a whole. For the guidance of research policy, however, and still more for ordinary work, the problems and circumstances of the main component areas must be considered. This matter we deal with in Section VIII.

SECTION III.

THE FIELD OF RESEARCH ON TEA GROWING.

24. In Section II, from a consideration of the economic situation, we have drawn certain general inferences as to research. Keeping these in mind, we proceed now to review the whole field open to research on tea. We believe a survey of this kind to be essential before a programme of experimentation is adopted. Tea problems provide an immense field for enquiry and it is necessary to concentrate effort along a limited number of lines. These should be chosen for their importance to the industry, combined with suitability for experimentation. Care in choosing the lines of enquiry is necessary in all crop research. With tea it is outstandingly important. For, as with all perennial crops, results can be accurately measured only by continuing observation over many years. Moreover, tea presents certain problems, notably those of quality and of plant breeding, which, for inherent difficulty, are paralleled by those of very few other crops.

25. Briefly, the objective of research on tea, is to help the producer to get from the land the greatest possible nett monetary return per acre. It must, therefore, seek means for raising the gross return per acre and, at the same time, of reducing costs of production. It follows that no experimental result can be finally translated into practical advice until it has been tested in terms of income and expenditure. Such testing must make careful allowance for all practical circumstances, *e.g.*, a cultivation may be cheap when labour is freely available but expensive to the point of impossibility when there is a great pressure of other work. We think that on the question of labour costs, greater clearness of thought is in some cases called for. For instance, it is claimed from experiments that no deep hoeing is necessary. The reply is made that a labour force must be kept, equal to the peak demands of plucking and other work in the rains. Now this force must be given a chance to earn a minimum cash wage in the cold weather when the total work to be done is relatively

little. Consequently deep hoeing is welcome and to argue that surface hoeing in the cold weather saves money, is to ignore the practical consideration that a job must be found for the labour. To this the counter retort is that labour (and wages) saved from cultivations could profitably be diverted to more care in pruning. And so the argument could go on. The industry must settle questions of this kind for itself and we go so far as to say that in some places it suffers from a tendency to reject any application of experimental results by indulging inconclusively in labour requirement arguments of the kind we have reproduced. Setting aside, with these provisos, the question of production costs, we may begin our survey of the field of research by considering the factors which control gross monetary output per acre.

26. Gross monetary output per acre is determined partly by yield per acre and partly by price per pound. This latter (at any given general price level in world markets) is decided by the the quality of the tea. Yield and quality are inter-related. For instance, fine plucking, while reducing yield, may raise quality and, therefore, price. This inter-dependence must naturally be studied in research just as, in commercial practice, estates should decide according to their circumstances, the levels of yield and quality at which it is appropriate for them to aim. Quality is affected both by tea growing and by tea making. We find it desirable, however, to deal separately with yield and with quality in surveying the field of tea research. The present Section (III) and Section VI are, therefore, respectively devoted to : tea growing and tea quality and manufacture.

The Factors Affecting Yield of Tea.

27. It may be said, in terms customary in botany, that the yield of any crop depends partly on the external factors and partly on the internal factors. The external factors are all the influences exerted on the crop by nature such as weather and type of soil, and all the influences exerted by man such as hoeing, manuring, pruning, etc. They constitute, in fact, the whole environment of the crop. The internal factors which

control yield (and quality also) are the factors or properties of the plant itself. They are no less important than the environment but are much more difficult to think about, or describe, or measure. We know them only through the effects they produce and it is through these effects that we can most easily describe them, as a simple illustration will show. Thus, a typical dark leaved Manipuri jat differs from a typical light leaved Assam jat in several ways. One of these is in leaf colour. We say that the Manipuri has a factor causing dark leaf which the Assam lacks. Actually, the difference in leaf colour may be caused not by one factor but by several. The two jats differ, of course, in many other ways, *e.g.*, in hardiness and all these differences arise from the presence or absence of certain internal or plant factors. The number of factors in which the various jats differ and the effects of these factors on the appearance, growth, yield and so on of the bushes, could only be fully found out by elaborate cross breeding experiments. It must be presumed that every internal factor affects yield (and quality) to some extent. For instance, the factor for darkness of leaf has some influence on the yielding capacity of a Manipuri jat and this influence is absent in an Assam jat. Theoretically, therefore, the scientist should try to find out exactly what factors are present in every jat and how each influences yield and quality. But we know that for tea, as for every other crop, such an undertaking would be insuperably difficult, for the number of factors is unknown, but must be very great, while their influences are extremely subtle. In practice, therefore the botanical study of yield (and quality), *i.e.*, the study of the internal factors affecting it, must be restricted to such lines as are of obvious practical importance and, at the same time, reasonably favourable to scientific enquiry. There are, we believe, two such lines, *viz.*, developmental studies and plant breeding. In reaching this conclusion we have naturally considered the part plant physiology should play in tea research. Our view is that physiological investigations, save in the case of withering (see paragraph 150) are not at present appropriate save where as with certain diseases of tea, the line of advance is clearly physiological.

Developmental Studies of Tea.

28. In an experiment for comparing different kinds of manure or different soil cultivations, the interest of the planter is to know which manure or which cultivation pays best. But the scientist requires to know more than this. He must ascertain not only which particular treatment is best but exactly why it is best. This information he can get only from the plant itself. He, therefore, measures the growth or state of development of the plants under each kind of treatment, at regular intervals of time. This, he hopes, will show him at which particular time and at which stage of growth, every manurial (or cultivation) treatment affects the plant and, finally, how each of these effects influences the final yield. With this knowledge he may be able to suggest ways in which the best treatment can be still further improved by being made still more helpful to the plant at the periods of growth which experiments have shown to be specially important in relation to yield. This brief account explains the nature and the purpose of developmental studies, *i.e.*, periodic observations on the growth of the plants in an experiment.

29. In crop production research at large, it is now accepted that no field experiment, *e.g.*, on manuring, soil cultivation, etc., is fully satisfactory unless developmental studies are made. We consider it should be a principle to include such studies, whenever appropriate, in field experiments on tea. Now, to get accurate results, the growth of a great number of bushes under each experimental treatment must be measured at regular intervals. This means that some quick method of measuring growth must be found. With annual crops such as rice or beans the amount of growth can be satisfactorily and rapidly measured by counting the number of shoots and measuring their length. No such simple measurements are possible, however, with tea. With bushes in regular plucking, the yield of leaf from each bush at every round is itself an index of growth ; and from it the number of shoots plucked and their average size can easily be determined. But methods are needed for more accurately measuring

the growth of the tea bush and for use in the various conditions of the bush. Those growth characteristics which influence plucking, *e.g.*, relative size of bud to first leaf, etc., are of manifest importance here. The building up of such methods should, we think, be part of the programme of botanical work.

Plant Breeding.

30. We have suggested plant breeding as the second line of botanical work, *i.e., work on the internal factors of the tea plant. Our enquiries have led us to believe that in the whole field open to tea research, plant breeding is one of the two* supremely important lines of enquiry, the study of tea quality being the other. It must be made clear, however, that tea is in some ways a peculiarly difficult subject for plant breeding. Thus before proposals for work are made, the relevant circumstances must be carefully considered. Two facts are outstanding. First that every commercial jat is obviously a mixture of several different types of bush; next that, as various experiments have shown, the tea bush can be vegetatively propagated. These two facts must now be closely examined in relation to the methods generally employed in plant breeding.

Tea Jats.

31. Most of the tea in North-East India belongs to one or other of the classes known as dark leaved (or Manipuri), light leaved (or indigenous Assam) Burma, China, Hybrid and Lushai. The first two are the most important; the third is still sometimes planted; the last three occur in gardens but seeds are not in supply, for they are not now planted. The acreage and the exact geographical distribution of these classes of tea have never been found out. Their general suitability for the main tea areas, however, are matters of fairly good, general agreement. Within each class are several jats. As a rule a jat bears the name of the garden on which it is grown but a good deal of "once removed" seed is used. There are virtually no experimental results to show the value and suitability of the various jats for different areas and jats are selected on the basis of their general

reputation. Our many enquiries have led us to believe that the planting community has to rely far more on general, and by no means precise, beliefs, in the matter of jats, than on anything else. We consider the situation is unsatisfactory and especially in relation to the great general importance of the problem of replanting which we mention in Section II. Speaking generally the first step in any plant breeding programme is to ensure that the best use is being made of existing varieties while new varieties are being produced. This involves the identification and classification of all existing varieties, *i.e.*, for tea, all existing jats, the elimination of any synonymous names, (*i.e.*, two or more names for the same variety) and comparative trials of yield and quality in different areas. It is not necessary, of course, to test every variety in every district : the trial in any district should include only the varieties which may be expected from preliminary enquiry and general experience to be of practical interest there.

Comparative Tests of Tea Jats.

32. The steps outlined above offer exceptional difficulty in the case of tea. Here, as in most proposals for experiments on tea, quality is the crux of the matter. The amount of leaf from plot experiments is too small for manufacture on the ordinary estate; to get enough leaf of each variety for commercial manufacture would necessitate having excessively large plots; and even if such plots could be provided, the control and constancy of working of a commercial factory are probably not such as comparative tests of the quality of different jats require. It is therefore evident that the trial of jats for yield and quality in a number of different districts cannot be fully undertaken until means are found for testing quality in small-scale experiments. We have concluded, however, that comparative jat trial plots should, nevertheless, be started in the main tea districts of North-East India. They should be, we suggest, in the charge of the resident Advisory Officers whose appointment we propose in Section VIII. Such plots would show the relative yielding capacity of the several jats tried in each district as well as their

behaviour in drought, their susceptibility to disease and their general response to local conditions. They could also be utilised by specialist members of the Scientific Department for certain of their investigations. And further, they would be of the greatest value in connection with the work of single plant selection which in a later passage, we propose. Certain preliminary enquiries would be necessary in connection with the laying down of these jat trial plots, especially into the identity, general reputation, and geographical distribution of the various jats of commerce. The plots, we suggest, could be accommodated on suitable estates. In surveying the identities and reputations of all known jats, the Scientific Department would become acquainted with the seed supply situation in North-East India. We are convinced, from our evidence, that this situation should be critically studied. The object of study should be to decide whether the existing system of seed supply needs to be improved and if so, by what means.

33. In paragraph 27, for simplicity, we spoke of jats as if they were pure or uniform strains, *e.g.*, as if every bush belonging to the same jat were identical in all characters. It is well-known, of course, that in any block of tea, of any jat, great differences can be seen between one bush and another. There is, however, virtually no exact knowledge of the number of different types of bush to be found in any jat, of the proportions in which the different types occur, or of the characteristics of each type. It is a matter of common belief that some bushes are much better yielders than others and recent experiments in Java support this belief. How widely one type of bush may differ in quality from other types in the same jat there is, at present, nothing to show. The situation, therefore, is that on every garden the yield and quality of the tea are, in the case of each separate jat, dependent on an unknown mixture of different types of bush. Now it is true that in some cases, for certain crops, a mixture of types is preferable to perfect uniformity. But the idea naturally arises that it might be possible to select the few best bushes or even the best single bush from a jat and, by propagating it, to get a uniform

new strain much superior in yield and quality to the original, mixed jat. The success of selection work with rubber and cinchona and the preliminary experiments on tea in Java already referred to, lend support to this idea. Before going further into the possibilities of such selection work on tea, however, it is necessary to consider the two methods by which tea can be propagated. These are by seed and by vegetative means and they have a close bearing on selection.

Seed Production and Jat Impurity.

34. Tea is a naturally cross-pollinating plant. That is to say, most of the pollen which fertilises any flower, enabling it to form seed, comes not from that flower itself nor from some other flower on the same bush, but from a different bush. Although scientific evidence on this point is limited it seems probable that tea is very highly self-sterile. This means that a single tea bush if grown in complete isolation from other bushes could not use its own pollen to more than a very limited extent and would, therefore, be practically barren of seed. Many interesting matters arise from this high degree of self-sterility but it is only necessary to consider here those directly affecting breeding possibilities. These are :—

(*a*). Every tea plant raised from a seed is a hybrid.

(*b*). If a block of seed plants is not isolated from other bushes, its progeny will be more mixed in type than itself.

(*c*). If a small block of seed plants is isolated from other bushes, so that the plants in the block can inter-change pollen only with one another, their progeny will nevertheless probably be more mixed in type than they themselves are.

(*d*). By protracted experiment it might be possible to find self fertile types, *i.e.*, in which single plants could fertilise themselves. Experience with other crops suggests, however, that these might be very deficient in vigour.

(*e*). The only practicable method of getting seed and yet preserving a high uniformity of type with highly self sterile plants is, therefore, by "mass selection". This consists of picking out a small number of plants, all very closely alike, and all good for yield and in other characteristics. These plants are then grown in isolation from all others. They fertilise one another and the seed so produced gives a larger block of plants which are again grown in isolation. This process is continued until there is enough seed for commercial use or sale. It has to be repeated at suitable intervals of time. The fewer the plants taken in the first instance the greater the uniformity attained but the longer the time taken to raise any desired quantity of seed. Since the tea bush does not seed freely until about its tenth year, it is obvious that such a succession of selections would be out of the question for large-scale seed raising and of only limited application for experimental purposes.

Vegetative Propagation of Tea.

35. The alternative to propagation by seed is vegetative propagation. By this means there can be raised from a single plant any number of progeny plants all of which will be absolutely alike in all respects. Two different methods are used. In the first, shoots from the parent bush are made to root themselves, a variety of ways being employed for different types of plant. In the second method a bud (or a shoot) from the parent plant is budded (or grafted) on to another plant (the stock) which is usually first cut down almost to ground level. The second method does not give the complete uniformity of progeny plants which the first ensures unless all the "stock" plants are themselves absolutely alike. In tea the stock plants would not, of course, be all alike. But from experiments so far made it seems probable that, as with rubber, this might not be a serious objec-

tion in comparison with the advantages to be derived from selection. Further, experiments in Java show that separate measures can be taken to get a supply of fairly uniform seedling tea bushes for stocks.

36. In botanical language, all the plants derived from one single plant by vegetative propagation, are referred to collectively as a "clone". All plants of a clone are, as explained above, absolutely alike and an unlimited number of new bushes of the same clone can be produced by taking buds or shoots from the existing bushes and vegetatively propagating them.

37. Of the two methods of vegetative propagation we find it impossible to make choice. Each has merits and defects which may vary with the climate of the country concerned. We consider it essential that both should be further studied with great care since upon vegetative propagation must rest the hope of improving tea by plant breeding. One of the problems to take up ultimately is the effect of the stock on a budded plant. We think it desirable, however, to outline here a breeding procedure which is being provisionally developed in Java. The general idea is as follows :—

(*a*). To pick by prolonged observation a large number of individual bushes which appear to be outstanding in yield, vigour, and other desirable characters. Great numbers of gardens are visited for this purpose. The risk of picking a bush of poor type which happens to be growing on a very rich patch of soil is naturally realised.

(*b*). To create, by budding, a clone of about twenty bushes from each of these selected single bushes. The yielding capacities of these clones are carefully studied by weekly pluckings and the best few clones, for yield, are thus picked out.

(*c*). To increase the size of these selected clones by further budding so as to get enough material for accurate yield trials. From the results of these

trials a small number of the best clones is again selected. At this stage the very striking differences between one clone and another, in yield just as much as in appearance, and the extraordinary uniformity of the bushes constituting a single clone, are most impressive features of the work in Java.

(*d*). To multiply vegetatively the clones finally picked in the preceding stage so as to get enough material for accurate yield trials in several districts. These trials make it possible to select, let us say, two outstanding and similar clones in each respective district.

(*e*). To grow each pair of clones, so selected, in isolation so that they may interpollinate and thus give large stocks of seed for commercial use. Planting of seed from clones promises, in recent rubber investigations, to be a thoroughly practicable and valuable method.

An alternative possibility would be to omit the seed raising described in (*e*) and at some earlier stage to bud direct on to cut back bushes. In time, a commercial estate might thus be converted to one or more pure clones. Budding can now be done with such rapidity as to make this possibility worthy of attention.

38. The weakness of the above procedure, as workers in Java explain, is that, no small-scale tests for quality being known, clones have to be selected for yield, hardiness, etc., only. We revert to this point in paragraph 47 below.

Plant Breeding Possibilities.

39. Having now considered the characteristics of the tea plant which affect breeding, we turn to discuss the extent to which it is likely to be possible to employ with this crop, the various general methods now customary in plant breeding. There are four of these: introduction; mass selection; single plant selection; and hybridising.

The Method of Introduction.

40. This method consists, for any crop, of introducing and testing, in the country concerned, as many varieties as possible from other countries. An introduced variety may prove to be sufficiently good to take into general cultivation at once. More frequently, however, introduced varieties have proved valuable not for general use but because some special feature, and notably disease resistance, makes them important for breeding by hybridisation. For North-East India, the introduction of teas from other areas is likely to hold no promise save in one respect. Available evidence suggests that the wild or semi-wild teas of Assam and adjoining territories have not yet been exhaustively studied. We consider they should be examined with the object of finding types possessing features, especially disease resistance, not present in any of the cultivated teas. This undertaking should be part of the general tea selection proposed in paragraphs 42—46.

The Method of Mass Selection.

41. Mass selection has been described in paragraph 34 (*e*). Its basal principle of using as seed bearers only plants of special merit is, nominally, of course, inherent in the existing procedure for raising commercial stocks of tea seed. We have already recorded in paragraph 32 our opinion that a critical survey should be made of the seed supply situation in North-East India. In Java a special form mass selection is being developed. The best available seed is closely planted in nursery beds and then, by successive weeding out, all but the twenty per cent most vigorous plants are removed. These are then planted out in the ordinary way. The experience is that not only do plants so selected grow into very vigorous bushes but also that the bushes are more uniform than those planted out from the nursery without selection. It is proposed to employ this method for raising more uniform stocks for budding. This form of mass selection appears to us to deserve consideration in North-East India.

The Method of Single Plant Selection.

42. The first step in plant breeding is to ensure that the best use is being made of existing varieties. To that end we

have in paragraph 31 recommended that comparative trials of tea jats be made. The next step, if existing varieties are found to be mixtures of different types, is to select promising single plants, propagate them into populations or bulks large enough for testing, and then to carry on the best for commercial use. This method of selecting single plants is, of course, more refined and necessarily slower, than the mass selection already described. Now the greater the impurity or variability of a commercial variety, *i.e.*, the more different types of plant it contains, the greater the possibilities awaiting single plant selection. Tea, in which every jat displays great differences between one bush and another, seems certain, therefore, to yield important results.

43. Every garden in North-East India is potentially a source of specially valuable tea-types or selections. It is thus clearly desirable that the search for types should be as wide and exhaustive as possible. Some jats, no doubt, will prove more valuable sources than others and in this matter the comparative jat trials recommended in paragraph 31 will be a guide. The procedure of testing and propagating selected single plants is familiar to all plant breeders. Some of its special features, for tea, are considered in paragraphs 34 and 35. We think it necessary to call attention to two others, *viz.*, the classification of tea types or selections and their permanent preservation.

44. To handle and judge many thousands of selected single plants from many different sources, the plant breeder must group them into classes. His ultimate interest is only in yield, quality, and other practical features, but any characteristics, *e.g.*, shape of the tip of the leaf, which helps him to perceive differences in bush type, is important. He must, in short, construct a complete botanical classification of all the types he is able to find. Advances in the study of the physiology of withering and of the chemistry of tea leaf will, it is hoped, enable him in time to include some quality characteristics in his classification and possibly also to correlate some botanical characteristics with quality. We consider it a point of much importance to evolve if possible, a botanical classification which can be em-

ployed by tea research workers in North-East India, South India, Ceylon and the Netherlands Indies. The use of a common classification would promote conjoint work and increase the general value of research carried out in any one country. For the first stages of classification a simple basis should be adopted, using plant characters which are easy to judge. Refinements can come later. The study of tea classification bears on the evolving of methods for developmental study (see paragraph 28). A preliminary examination of the chromosomes should be made when the main tea types have been classified. To spare the Botanical Branch the labour of this, arrangements could be made for it to be done at home on preserved material.

45. In single plant selection, types are often found which, of no immediate commercial value, or of apparently only the second order of promise, may yet be wanted later. These are usually preserved in a museum collection. It is desirable to make this collection as complete as possible for purposes of reference. For instance, after the first search for promising single bushes, attention will from time to time be called to yet other outstanding bushes—possibly by planters. These may be of types already examined and discarded or they may be entirely new to the selectionist. With his classification and his living museum he is able to settle questions of this kind. If any wild or semi-wild teas of interest are found (see paragraph 40) they should be included in the museum. Budding (or some other form of vegetative propagation) would, of course, be used in transfering a selection to the museum.

46. North-East India's position, in the matter of selection, is unique. The other cognate tea areas have drawn on it for seed and it could, therefore, build up a richer collection of teas, by single plant selection, than any other country. If conjoint action in research is effected, North-East India could make a great contribution by establishing the kind of type museum and classification which have been described. To give the museum its greatest potential value while limiting its size and maintenance will need careful planning.

47. *It is obvious that single plant selection, however great* its potentialities, can bear no practical fruit until means are found for testing quality with small amounts of leaf. The policy of extreme caution would be to defer selection until small scale quality testing had been perfected. Having regard to the scope for selection, to its inevitable slowness and to the impressive preliminary work already done in Java, we do not recommend extreme caution. In our view both quality tests and selection should without delay be made primary features of the Scientific Department's research programme.

The Method of Hybridising.

48. It is a principle to exploit all other methods of breeding before taking up the more elaborate but more potent method of hybridising or cross breeding. With self-sterile plants, it can only be used in some modified form. The special modification for tea would clearly be to combine it with vegetative propagation. By crossing two single plants, one good for yield and quality, the other, say, poor in general but resistant to some serious disease, it might be possible to get a hybrid plant combining the merits of both parents. This would not breed true from seed but could be propagated to any desired extent by vegetative means. We do not discuss the many difficult questions which hybridising in tea would bring up, for it is clear that until selection has been actively pursued this more complicated method need receive no attention.

Root Studies.

49. The study of tea morphology, *i.e.*, the structure of the parts of the tea bush, has been recommended in connection with both developmental studies (paragraph 28) and tea classification (paragraph 44). No part seems more evidently of practical interest than the root and yet, as most painstaking work on several other plants shows, none is more difficult to study. Cheap labour, skilled in handling the soil is, however, a substantial asset, for root investigations consist largely at first of excavating the roots of fully grown plants. With tea, several circum-

stances point to the immediate importance of root study and among them are : the allegation, and the denial, that deep cultivation injures the root; that it thereby induces root disease ; the great difference in height of water-table between the rains and the driest period of the year ; the prevalence of drought in many areas; the possibility that hardness of subsoil often hinders root penetration. Our conclusion is that root investigations should be commenced as soon as possible (see paragraph 103). Their form should be decided after consultation with workers in Europe who have specialised knowledge. Comparative root development in different jats and on different soil types would be valuable complements to other branches of work recommended in this Report.

The External Factors of Yield.

50. In the opening passages of paragraph 27 the meaning of internal or plant factors and of external or environment factors was explained. The lines of research on internal factors having been discussed in paragraphs 27 to 49 we turn now to the external factors. These may be grouped under four headings according as they are associated with climate, soil, (including manuring), disease, and cultivation (including pruning and plucking). The field of research which opens under these respective headings we now proceed to discuss. It will be recalled from paragraphs 28 and 29 that in our view developmental studies should, so far as possible, be carried out in all experiments on external factors of yield.

Climatic Factors.

51. Climatic factors include total rainfall, its distribution throughout the year, altitude, and temperature. These are uncontrollable but their study in relation to the growth of the tea bush might be undertaken with three purposes in mind. First, if yield and quality could be correlated with climatic factors, forecasts of yield and quality might be made. Next, such studies might help in the adaptation of local practice to local climate. Finally, they might help to determine the limits, especially of

quality, above which any particular set of climate conditions make it impossible to go. Our conclusion is, however, that studies of this kind for tea in North-East India would not be repaid by the great effort they would require.

Shadetrees.

52. Since, if we may take the name to imply the purpose, shadetrees represent one of the few ways of controlling climate, they may appropriately be considered here. Our enquiries convince us that the functions of shadetrees in the various districts are matters of individual opinion which shows great variation. There is no less division of opinion as to the actual benefits from shadetrees. Moreover, we have been much struck by finding in many places the shadetrees so few and so irregularly scattered as to result in neither shade nor absence of shade as a whole. More certain knowledge concerning shade is clearly necessary but the matter is of great complexity. Shade theoretically affects the soil in respect of temperature, loss of water, addition of organic matter from fallen leaves, breaking up effect on sub-soil, and in other ways. It affects the tea bush by reducing the intensity of light on the leaves and so influencing loss of water from the leaves and other functions. Upon all these questions, however, there is no certain information whatsoever and how shade in its various degrees and forms affects, and theoretically should affect, yield and quality, are completely in doubt. There are also questions as to the best species of shadetrees, their liability to diseases which may also affect the roots of tea bushes, the length of their life and the expense of removing dead or fallen trees. Extremely large-scale experiments would be necessary in connection with shade and we think that before any further experimentation is attempted, a critical survey of the existing facts and beliefs concerning this matter should be made all over the tea districts. Work of this kind could be well done by the proposed Advisory Officers. It must be remembered that shade effects will never be clearly expressible in the form of monetary cost and return which is possible in the case of manuring.

Soil Factors and Manuring.

53. We have considered with care whether a full soil survey of the tea areas should be made. Our conclusion is that this is not required and that the partial surveys already done by the Scientific Department are sufficient. Our reasons are that soil surveys would be of no value for tea unless accompanied by numerous local field experiments (which have not yet been made). Further, manurial experiments and cognate work up to date suggest that nitrogen alone of the manurial elements produces effects of practical importance and that detailed soil analyses are unlikely to be necessary, save in the rare cases of alkaline patches, etc. We are constrained to remark that many estates still fail to realise that in normal cases soil analysis alone affords very little guidance indeed to manurial requirements. The Advisory Officers, if appointed, will no doubt in time make soil type surveys for their own purposes.

54. In a few special areas, for example Bhil soils and areas of very low productivity, special soil studies may be necessary but it would clearly be undesirable to devote much time to these exceptional cases. Soil acidity presents still some unsolved problems, e.g., the upper limit of soil acidity for tea. We think, however, that these deserve little attention because of the claims of other matters.

Drainage.

55. Unfortunately we have not been able to inspect the tea districts in the rains. We have, however, discussed drainage and inspected draining work in many places. We think that the principles of drainage, as generally understood in agriculture, are a sufficient guide for tea estates if properly applied both in respect of surface water and the water table. There is evident a strong tendency to be bound by custom in draining and it seems probable that in many cases unnecessary drains are cut. This apart from wasting labour undoubtedly causes some drying out of the soil. Further, it is not always fully realised that to put drains in wet places is not necessarily right. Drains which

take the water which would otherwise create wet places are frequently the real requirement. Very interesting research could be done on the depth and distance apart of drains but it would involve large areas and, moreover, to place a value upon the results of draining is notoriously difficult. We suggest that the Advisory Officers, if appointed, be encouraged by the Department to take a special interest in draining and then to make close observations on the drainage situation in their own areas.

Soil Erosion.

56. Soil erosion is apparent in certain situations, *e.g.*, tilah land, but the remedies are well-known and it may be left to Advisory Officers, if appointed, to advise as to their application, if requested.

Manuring.

57. Manuring is a matter of great immediate importance in relation to both yield and quality and it opens up, also, the more distant and grave question of soil deterioration by which some minds are troubled. Our evidence has not led us to fear general soil deterioration in the tea districts in spite of cases reported to us of the impossibility of replanting with tea, areas which have carried the crop for sixty or seventy years. Of very successful replanting we have had much first-hand evidence. Planting circles and to a greater degree the tea interests in London, are apprehensive of soil deterioration from the use of inorganic manures, from which practice they also expect that loss of quality and of the health of the bushes may result.

Organic Matter in Soils.

58. This burning question must be thoroughly investigated. One interesting fact is that the weight of prunings and weeds put back into the soil exceeds what is removed by plucking. This does not, however, prove that the organic matter content of the soil can be disregarded but it should not be overlooked by those who without experimental proof have insisted on the

superlative need for constant additions of organic matter to tea soils. These assume that it is an easy matter to maintain a high organic content of the soil, forgetting the difference between adding organic matter and increasing the permanent organic matter content. In our view the first need is direct experimental test to see whether organic matter other than prunings need be added to tea soils; for what specific reasons such addition is necessary; and what purposes such added organic matter serves in the soil which inorganic manures cannot serve. Such tests are extremely difficult to design because there seems no clear way of separating by experiment the manurial from the other effects of organic matter. It goes without saying that cost and monetary value of returns must be closely watched in all studies of organic soil matter. The best and cheapest way of supplying organic matter, if additions other than prunings prove to be necessary, opens up a further chain of questions. Composts must obviously be tried including those made without the use of animal excreta, *i.e.*, using inorganic nitrogen. A number of estates, some of which we visited, are making composts on a fairly large scale, and the opportunity should be taken to find out with their help the costs involved. Determination of cost in a matter of this kind is well-known to be full of pit-falls. If it should be proved that additional organic matter is essential for tea soils, then at some later date questions like the possible making of cattle manure, using rice straw, etc., with the excrement might have to be considered.

Soil Nitrogen.

59. What has been said in paragraph 58 shows how interesting a field is presented for the study of soil nitrogen in tea land. This subject is, of course, interesting in all countries, but especially perhaps in the tropics, and one of its cardinal features is bacterial action. Considering the great difficulties which even the most specialised laboratories are encountering in studies of soil nitrogen and soil bacteria and the numerous cases in which relatively small scientific laboratories have failed to make head-

way with this subject through insufficiency of staff, we conclude that the Scientific Department would not be wise to carry on investigation in this matter.

Inorganic Fertilisers.

60. Apart from the question of inorganic *versus* organic fertilisers already dealt with, there are the customary questions of the influence of nitrogen, phosphorous, and potash on yield and quality. These are of high importance and are, moreover, the subject of violent prejudice in the minds of some planters, brokers, and Agency Houses. We therefore suggest that they should receive concentrated attention in experiment. The line of action is clearly to extend the essential experiments into as many tea areas as possible rather than to pursue refinements in one place. There are cases where valuable information on manuring has been gained from simple plots, often unduplicated, which have been maintained for a considerable number of years. We think that certain of the Borbhetta plots, though not laid out on modern lines, should be carried on for this reason. The question of recovery rates of fertilisers has interested us. It involves the ratio between the amount of fertilisers applied to the soil and the amount of the different manurial elements recovered from the bushes in the form of pluckings and prunings, and permanent wood. Facts given to us by the Chemical Branch convince us, however, that the matter though interesting does not call for experimental study in North-East India. It is quite possible that many cultivation and other effects will show fairly strong inter-actions with manuring. That is to say, for example, the relative effect of one kind of pruning compared with another might be different under different manurial treatments. This general possibility—which is familiar in all crop work—suggests the desirability of a policy of relatively few but complex experiments by means of which such inter-actions could be tested. This possibility should be borne in mind but it does not, we think, call for further comment here.

Disease.

61. We consider under this heading the injury to tea bushes from fungi, also from insects and other small organisms. Before discussing the fields of research concerned we must deal with questions frequently asked or implied in connection with many crops, including tea. When a serious pest or fungus has been prevalent for several years, crop producers clamour for a mycologist or an entomologist. It often happens that after a time the parasite, for unknown reasons, diminishes greatly in seriousness. The tendency is then to ask whether it is worth while to have, let us say, an entomologist, when no insect is for the time harming the crops. Or the pest may continue its ravages and the entomologist his researches, for many years, without the industry being provided with an effective control. It is then bluntly asked, as we know from our experiences in tea, whether it is worth while to keep an entomologist if they cannot provide remedies. Now we feel that the tea industry must think out its answers to questions of this kind and adopt in regard to disease research a stable policy. Intermittent research, with breaks of several years, is certainly of no use and if a Mycological or an Entomological Branch is to be included in the Scientific Department it must be as permanent as any other Branch.

62. We asked many official witnesses and individual planters whether they desired the continuation of mycology and entomology in the Scientific Department. As a whole their replies were very strongly in favour of both. Our own view is that the economics and the facts as to disease in tea, make it a wise and not very costly insurance to support research on both insects and fungi. In saying this we have given very careful attention to the achievements of these branches of science with crops in general and we realise that in many cases prolonged study has failed to produce effective remedies. By maintaining a Mycological and an Entomological Branch the tea industry makes sure of nothing but earnest investigation. By not maintaining them it saves some money but runs certain risks. To estimate these risks is virtually impossible. Tea has an unusual

freedom from pests and diseases, compared with most of the world's important crops. But the actual damage to tea from parasites is not to be ignored and there can be no guarantee it will not increase. We suggest one other consideration. The results of the experimental work done by any scientific branch are by no means the measure of the knowledge it places at the disposal of the industry. In any subject—let us say entomology—active research is being carried on in practically all the countries of the world and on a vast number of crops. A discovery concerning a pest of the oil palm in the Belgium Congo might provide a new general principle which could be applied to tea. But unless the tea industry had its own entomologists it might even remain unaware of such a pertinent discovery and would have no one with the special knowledge to apply it to tea. We now deal in turn with the field of research in mycology and entomology.

Mycology: Fungus Diseases.

63. Only by a very thorough survey of the tea bushes all over North-East India, with visits in all the seasons of the year, would it be possible to get the information on which to base final decisions as to the field of research in mycology. From the evidence available to us, including planters' views and the substantial information collected by the Mycological Branch, there appear to be two fairly clearly defined types of disease requiring attention, *viz.* :—

(*a*). Those which occur epidemically and can be attacked by direct means. Examples are black rot (*Corticium invisum*), and blister blight (*Exobasidium vexans*) for which spraying is effective; other examples are such root diseases as *Ustulina zonata* and *Fomes lamaoensis* which can be dealt with by properly arranged digging out of bushes.

(*b*). Those which are endemic, being found freely on most tea gardens and under most conditions and

which cannot be directly attacked with much success. The important members of this group are those associated with the primary stages of decay of the main branches of the bush. These apparently enter at pruning cuts and accidental breaks and lead to the destruction of the whole bush. Although no adequate data are available it seems certain that fungi of this class do far more damage to tea than do those of class (*a*) and possibly ninety per cent of infillings are required because of their action. They are not obligate parasites and it is supposed that the true, initial cause of trouble, is the physiologically unsound condition of the bush.

The field of research may now be considered for each of these groups of disease.

64. With the diseases of class (*a*), improvement of the methods of direct attack is obviously the policy. Methods must naturally be finally judged on a monetary basis, the cost of treatment being compared, as closely as possible, with the value of the increase in crop. It must be considered as a part of the field of research to develop spraying and other methods so as to make them as easy as possible for planters to apply; and further to take steps to check what planters actually do in order that they may neither waste their money nor, as we submit they have sometimes done, condemn a method which they have imperfectly applied. Modern spraying technique, *e.g.*, in fruit growing, is highly developed and every detail of it should be studied in relation to tea.

65. The field of research for diseases of class (*b*) paragraph 63 is far wider and more difficult. Certain forms of direct attack are possible but they are no more than palliatives. It is evident that no substantial progress will be made without great advances in knowledge. The entry into the wood, and the damaging activities there of fungi of this class are not likely to be understood unless the physiological state of the bush is related

to the growth requirements of the several fungi. An understanding of this difficult matter must be coupled with a knowledge of the factors, including soil, pruning, plucking, etc., which control the physiological state of the bush. A grasp of all these matters might be expected to make it possible to devise successful treatments.

66. In connection with the relation between physiology of the bush and incidence of disease, it has become customary with some to say that the surest way of dealing with diseases (and pests) is to keep plants healthy. We do not presume to discuss this much repeated idea but we suggest that it has misled many readers of tea literature and is too general to afford useful guidance as to the field of research in tea mycology and entomology.

67. The full scientific knowledge we speak of in paragraph 65 could only be obtained by elaborate, highly specialised studies in plant physiology. We feel that in present circumstances these must be ruled out of the field of mycological research in North-East India. Every tea area, however, needs physiological knowledge in relation to disease, and our suggestion is that endeavours be made to provide adequately in one area for this branch of enquiry in the interests of all (cf. Section XI). Excluding as impossible a fundamental physiological attack, it becomes necessary to seek for simple methods, if such be possible, by which the physiological state of a tea bush can be judged. Using these, it would be possible to find out the effect of manuring, cultivation, and other treatments on the physiological state of the bush and similarly to find out its relationship to attack by various fungi. In this way theoretically, manurial and other treatments could be discovered by which the bush could be kept in a state unfavourable to fungus attack. This, very briefly and crudely, is the idea behind a study of the problem by "field physiological" methods. We do not presume to condemn the idea but are doubtful about the results likely to ensue from it. A great deal depends on the trustworthiness of quick, approximate, physiological methods and we feel that the

form of mycological enquiry we have been discussing should not be prosecuted until expert physiological opinion has approved the physiological methods it is proposed to employ. That the physiological condition of a plant (or animal) may be considered to result from, rather than to induce attack by, a disease, is a familiar comment which cannot be ignored.

68. Much may be learned, and much that it is indispensable to know, by very thorough observation in all types of soil, climatic, manurial and other conditions, on commercial estates. This observation should be made with the purpose of trying to draw general, tentative inferences as to the relation between jat, environment and disease, as a guide to enquiry by specific experimentation.

69. Some tea fungi occur on other plants beside tea, including shadetrees and the relation of shade-trees to disease is clearly a matter for enquiry. It occasions anxiety in planting circles.

Entomology: Insect Pests.

70. In all our discussion and visits to gardens, as well as in other ways, we took particular care to get an idea of the extent of insect pest damage. Taking North-East India as a whole there is undoubtedly great concern about red spider and mosquito blight; and uneasiness about white ants. Although spraying has been much used against red spider, we heard many allegations of its uselessness. Failure had undoubtedly in some cases been caused by wrong procedure and in others by reducing the officially advised sprayings in order to save money. The facts concerning mosquito blight, its prevalence, the harm it does and the scientific investigations formerly made on it at Tocklai, are sufficiently well-known to render restatement unnecessary here. In the case of white ants, uneasiness is based, it is stated, on misapprehension. There is a form of white ant which in certain circumstances attacks healthy tea wood. Generally, however, the white ant comes in as a scavenger on wood already in decay from other causes. There are, of course,

many other pests of the tea bush in North-East India. Some of these have, in relatively small areas, done considerable damage for a short time. Repetitions of such sporadic trouble are certain to occur.

71. We have weighed most carefully the considerations as to the resumption of research in entomology, including cost. Our recommendation is that this Branch be restored by the appointment of a very carefully chosen European Officer. His work should be both advisory and research. The field of research should be : first to perfect spraying for red spider; next to resolve and explain in the areas concerned, any doubts as to white ant damage; next to resume the study of mosquito blight. In practice the three pests would no doubt come under study at the same time but it would be wise to try to score a practical success with the simpler cases first.

72. Investigations on mosquito blight should be most carefully planned. All past work should be critically re-examined and its results made use of as far as possible. A thorough survey of the problem on estates in every tea district should be made before adopting a programme of research. Useful guidance as to this survey could be furnished by the experiences of the Mycological Branch upon disease incidence in relation to environmental factors. We feel that the resumption of entomological work will only be justified in the hands of a highly qualified entomologist who by training and instinct is prepared to keep his studies always directed to the industry's major problems.

Cultivation.

73. We have, for convenience, included under the general heading of cultivation not only hoeing and other work on the soil but also pruning, plucking, nursery work and similar matters. All these things have great ramifications and yet in a way are less important than others, such as manuring, because in respect of them, accumulated planting experience has led to more precise ideas. Nevertheless there is still much strong prejudice

and lack of understanding and we have been surprised to be given in a number of cases as a reason for the cultivation (or manuring) policy adopted, the fact that "so much per acre is allowed for this". We concern ourselves only with what appear to us to be the main issues.

Spacing.

74. Upon this always interesting question no systematic experimentation has been carried out in North-East India, and we think none is at present necessary. The case for an interval of 4′ to 4′ 6″ according to the rainfall and soil seems generally agreed. The claims for triangular planting, especially in relation to symmetry of growth of the bush, seems strong.

Cultivation of the Soil.

75. The Commission has been struck with the diversity of opinion and practice in soil cultivation even within relatively small geographic areas. No one now seems to demur to the contention that the old, very deep cultivation including trenching, formerly given, was wrong. There is, however, a great reluctance to consider to what extent cultivation could be reduced and what are its real purposes. Consideration of these matttrs is with tea as with other crops, much clouded by the persistent though quite unjustified conviction that the deeper the cultivation the better the aeration of the soil. There are in planting circles opponents of deep cultivation but they in the main appear to base their case on the damage it does to the roots of the bushes. Now the Scientific Department has taken a definite stand in this matter. It has claimed to show from its experiments that cultivations are necessary only for the control of weeds and it has favoured surface cultivation, *i.e.*, creation of a fine mulch on the top as a protection against evaporation in drought periods. In so far as we are justified in coming to a conclusion on a matter of this kind, we wholeheartedly support the Scientific Department. We think that the field of research in soil cultivation lies in thoroughly testing, in as many districts as possible, Tocklai's main contentions. We have, in paragraph 49 suggested root

studies and in these the effects of damage to roots by cultivation to varying depths might well be included together, of course, with the effects upon growth and crop as a whole. Attention is again called to the question of labour costs dealt with in paragraph 25.

Plucking.

76. In this matter again there are very wide variations of practice and, therefore, possibilities of experiment. We suggest that attention be concentrated on two things, namely, fineness of plucking (coupled with degree of breaking back); and frequency of plucking—a difficult subject for experiment but important in practice.

Pruning.

77. The three points to which we suggest attention should be devoted are :—

(*a*). loss of bushes from decay setting in at cut surfaces;

(*b*). simple cutting across with various degrees of cleaning out including none at all;

(*c*). time of pruning.

There can be no doubt that the most important of these is (*a*), that is loss of bushes, and it is doubtful whether any matter under our general heading of cultivation is of greater practical importance, and therefore, deserving of a bigger share of attention in experimentation. We do not suggest any line of enquiry which has not already been taken up by the Scientific Department but wish to insist on the great importance of repetition of experiments in all localities, for as local witnesses have made clear to us, losses of the kind we have in mind occur to varying extents in the different districts. What we saw in our visits led us to believe that a thorough study of the facts as to loss of bushes in the different tea districts would be well repaid in the form of guidance and perhaps new ideas for experiments. Survey work

of this kind could, of course, well be done by local advisory officers. That heavy pruning may induce death for physiological reasons is a possibility which only specially planned experiments can probe (cf. paragraph 251).

Other Matters of Cultivation.

78. We have considered and sought advice locally upon many other things including: nursery work; bullock or buffalo cultivation among young bushes; infillings and large-scale replanting. These have not suggested to us any matters of importance to include in the field of research on tea growing other than those which have been reviewed in passages above.

Recommendations.

79. We have now completed our survey of the field of research on tea growing . In the course of this we have made suggestions and recommendations as to lines of enquiry which should be followed. These jointly constitute more work than the Scientific Department, as now made up, could undertake. It is to be hoped, however, that co-operation in research among tea areas, as proposed in Section XI, will enable each individual country to limit its investigations appropriately. Until this possibility has been fully examined, the final choice of lines of research in North-East India cannot be made.

SECTION IV.

PAST AND CURRENT RESEARCH ON TEA GROWING.

General.

80. We have considered in detail the work at present in hand and that which has occupied the Scientific Department during the past few years. It would, however, result in excessive length to refer in this Report to individual investigations. Moreover, our terms of reference require of us an opinion on two general points : as to whether the expenditure on research work by the Indian Tea Association has been well repaid ; and as to whether any major changes in this Scientific Department seem desirable. We speak, therefore, in these observations, of policy and main trends rather than of experimental detail.

81. Our questionnaire gave all sections of the tea industry the opportunity to criticise every side of the work of the Scientific Department. As may be seen from Appendix I, a variety of criticisms of its research work was offered. Many of these are dealt with in other parts of this Report (especially in Section VIII). Two of which must be specially mentioned here are the contact between the Department and the industry and the question of publications.

82. In our view, contact with the industry has not been as effective in the past few years as was necessary to keep the Department properly aware of the problems and circumstances of practical tea growing. A very important factor in the situation has been the almost complete suspension of tours by the Chief Scientific Officer and his colleagues during the past four years. A reduction of Staff led to this suspension on the ground that experimental work which it was essential to carry on, needed the whole time of the small remaining Staff.

83. The unsuitableness of the form in which the results of research have been made public, is commented on in later passages of this Report (*e.g.*, paragraph 237). We consider it has made it difficult for the industry to grasp the purposes of the

Department's numerous experiments and the exact bearing of their results on commercial practice.

84. There has, we think, been a tendency to disperse effort over too wide a field. This has arisen from a desire to embrace all enquiries which seemed relevant but has sometimes resulted in issues, not always small, being taken up and then abandoned for want of time. The chemistry of tea furnishes some examples of this.

85. The choice of problems and lines of enquiry has not always, in our view, been sufficiently directed by the economic situation and problems of the industry. We take as an example of this the physiological bias at first given to botanical work, the claims of plant breeding being for some time subordinated.

86. During the past few years, an excellent spirit of joint working has been in evidence among the various Branches, a result we attribute in large measure to the internal policy of the Chief Scientific Officer. To get the best results, however, joint work should not be left solely to good personal relations, impossible though it is without them. Conjoint action is necessary in planning work. If every Branch draws up its programme of work independently, it is certain to be too occupied to help another, when asked to do so, save in small incidental ways. Another way of expressing these ideas is to say that problems should be selected and attacked by the Department as a whole instead of the Chemical Branch (let us say, for illustration) selecting chemical problems, the Botanical Branch botanical problems and so on. More concerted action by the Chief Scientific Officer and his Staff in choosing problems and settling the main lines of attack would, we believe, be possible and advantageous.

87. The Chief Scientific Officer and his colleagues have been good enough to give us their views as to necessary Staff increases. We have noted these but have decided to make no recommendations at present other than for: Advisory Officers; an Entomologist; and a trained Indian Assistant for the

Botanist. These are urgently needed. Other Staff questions should be deferred until the possibilities of co-operation in research (see Section XI) have been followed up.

Botanical Branch.

88. This Branch was started in 1930 with the aid of a grant from the Empire Marketing Board who, until the present year, have paid half the initial and half the current costs. It is a matter for much gratification that the action of the Board led the Indian Tea Association to found this Branch. In our opinion it should have come into existence many years sooner. Without the slightest reflection on any other Branch, we say that it would have been wiser if such money as the Indian Tea Association actually spent had been so allocated as to make Botanical work possible at a much earlier date, although this would have involved a reduction in this work of the other Branches as a whole.

89. We very strongly recommend the keeping on of the Botanical Branch in spite of the termination of the Empire Marketing Board's grant.

90. The Branch was started primarily for physiological work together with the associated morphological and anatomical investigations. The study of varieties—the ultimate object of which is plant breeding—was a secondary consideration, though it has recently strengthened as the botanist has gained experience of the tea industry. This was, in our view, a wrong orientation. Plant breeding was the obvious line to follow and our suggestion is that the branch should, as soon as possible, make this its primary concern.

91. In plant breeding the object must be to breed. This seems self evident but nothing is easier than to be led away from the main purpose by the many intriguing scientific problems a plant breeder's work reveals to him. All the successes in plant breeding show the wisdom and the extreme necessity of making, at first, an empirical attack—empiricism being here defined by the methods used in connection with known plant breeding suc-

cesses. Refined morphological and anatomical work must be ancillary to and arise out of practical plant breeding. We are sure this consideration is superlatively important in tea, for "jats" are complicated mixtures of different botanical types. The problem of sampling, that is selecting for measurements a limited number of plants to represent the whole population, is excruciatingly difficult because of the mixed condition of the "jat". Moreover, at present the botanist can draw "jat" material for his refined studies only from small single plots. Minute measurement of clones (defined in paragraph 36) would, of course, be a much more rational and hopeful undertaking than similar work on jats. We understand that the Scientific Department is sometimes asked to identify and name a "jat", being given for this purpose a limited number of leaves often in a faded condition. The Department would be wise to make it quite clear to the industry that "jat" identification in these circumstances is impossible. It should only attempt identification when circumstances make this highly desirable and then in conditions it itself lays down.

92. We do not mean by this that the botanist's minute "jat" comparisons, in respect of leaf shape and hairiness of leaf, have been wasted work. Investigations of this kind were essential for experience in a field which no other tea botanist has ever seriously entered. We do, however, suggest that his present "jat" comparisons should be terminated with reasonable speed. His work on the hairiness of leaf should, however, we think, continue on present lines despite the objections we have mentioned, because of the accepted relation of that character to "quality".

93. The physiological, morphological and anatomical work has been largely in relation to plucking. We suggest that this, though it has given him valuable experience, should not be carried on. In present circumstances plant breeding holds far more promise of benefit to the industry than improvements in plucking and pruning. These practices, though not perfectly understood, have become relatively far advanced by the practical

experience of planters aided by the work of the Agricultural Branch. They contrast, in respect of general understanding, with seed supply and the suitability of different "jats" for various localities.

94. We do not suggest, of course, an abrupt termination of this physiological and anatomical work but that it should be directed towards those developmental studies of which we speak in paragraphs 28 and 29. From time to time morphological and other studies will be necessary in connection with plant breeding but they should be taken up for this purpose and not because of their inherent importance.

95. A review of the past work of the Branch shows that several small investigations were begun and after a short time given up. They served their purpose in giving experience but we perceive the need, in the past, for a programme of work based on the problems of the industry with careful consideration of the relative importance of these problems.

96. The Botanical Branch has not been as closely linked with the agricultural side of the Chemical Branch as the circumstances made desirable.

97. On the varietal comparison (plant breeding) side of its work the Branch might have profited greatly by close contact with research workers at home. The Research Station at East Malling has, as is well-known, explored with the greatest thoroughness, methods of varietal diagnosis by means of wood leaf, and other characters, and applied these with the most distinguished success. Contact with the workers there would have been very helpful. In matters of this kind the London Advisory Committee could give assistance.

98. Vegetative propagation, as we have explained in Section III, is one of the foundations of plant breeding. In tea it is at present being carried out by the Mycologist. We are convinced that this officer cannot give to this fundamentally important subject the time it needs. To transfer it at once to the

Botanical Branch and prosecute it vigorously is obviously necessary. Root studies, we regard as work the Mycological Branch should develop.

99. It seems undesirable for the Botanical Branch to take up yet further lines of work, such as the distribution of tannin in the leaf, which has been provisionally incorporated into its present programme of work.

100. The full range of investigation which has been contemplated by the Botanical Branch as logically necessary, includes both plant breeding and physiological and associated work. It would involve adding a second European Officer to the Branch. This we do not favour, and we adhere to our view that the Branch should make plant breeding its paramount occupation. A qualified Indian assistant should be added at once for work on vegetative propagation. A further small increase in the Staff will probably be necessary soon, *e.g.*, one qualified Indian Assistant, and one or two unqualified ones, when plant breeding begins to expand. As in the case of other Branches, however, we make no specific recommendations as to Staff because until the possibilities of "inter-area" allocation of research are known, the field proper to each Branch cannot be closely defined.

The Mycological Branch.

101. The range of work of this Branch has, for some years, been undesirably wide. It has included not only mycology on an extensive scale but also a considerable number of botanical investigations which were commenced before the Botanical Branch was set up.

102. We think that with the exception of root studies, botanical work should be given up in the Mycological Branch as soon as possible. The transfer of the study of vegetative propagation to the Botanical Branch we have already recommended. There is much data in the Branch relating to other botanical work including jat comparisons and the yield of individual

bushes. It would clearly be a wise plan to analyse this data and render it available to the Botanical Branch without delay. The Scientific Department has been very fortunate in having a Mycologist who, in the absence of a Botanical Branch, has been prepared and able to inaugurate botanical studies. The success achieved in vegetative propagation by leaf cuttings is noteworthy and may prove the foundation for the method ultimately to be adopted in North-East India.

103. In connection with diseases, root investigations have been made at various times. We have explained, in Section III, the ground we think root studies might cover and our suggestion is that the Mycological and Chemical Branches might be jointly responsible for them.

104. Mycological work itself has covered a very wide field, but has been directed to questions of practical importance and been based on understanding of tea-growing conditions including financial aspects.

105. Among the principal subjects of mycological research are:—

(*a*). Direct attack on fungi by spraying, uprooting, etc. Some of the spraying experiments have been of only partial value because they have done no more than demonstrate the percentage of infected plants in sprayed and unsprayed plots. To be fully useful, spraying experiments must determine nett monetary effects, *i.e.*, cost of spraying and value of crop increase secured by it.

(*b*). Mycorrhiza, *i.e.*, fungi living a joint life with the root of the tea bush, the nutrition of which it is believed to assist. We refrain from discussion of this notoriously difficult matter but suggest early consultation with specialists as to the advisability and form of continuing work on it. The great scientific interest of it cannot be

doubted especially, perhaps, in the case of the tea bush which is said to have a very limited number of root hairs. We have it in mind, however, that the field of research in tea mycology is large and that mycorrhiza studies are still very undeveloped in general.

(*c*). Physiological work, with the object explained in paragraphs 64 to 68. Whether the amount of reserve starch in the bush is the best index to physiological condition from the point of view of disease is a matter for question. Whether the rapid "iodine method" of estimating starch, which has been adopted is sufficiently sound, is another question. This latter apart from its chemical aspects presents difficulties in the problem of sampling, both in taking bushes from plots and roots from bushes. That the physiological work now in hand should not be abruptly terminated is, of course, obvious, but we think the difficulties call for early consultation with specialists both physiological and mycological.

(*d*). Yeasts in manufacture have been largely studied and resumption of this work is contemplated. We doubt the wisdom of this and suggest that, at the least, there should first be a very careful reconsideration of the evidence in favour of further work.

The Entomological Branch.

106. The Entomological Branch has been maintained in form of a reference collection under an Indian Assistant. It has served a useful purpose in connection with advisory enquiries. Its work, though modest, deserves appreciation. It was demonstrated to us that numerous type specimens could at once be produced for inspection, of pests ranging from the mosquito blight insects to bark eating caterpillars.

Chemical Branch.

107. *We consider here chemical work on soils and also agricultural experiments, leaving to Section VII our notes on investigations made by this Branch on tea quality and manufacture.* It may ultimately prove wise to deal with the very big range of subjects involved by setting up two branches—chemical and agricultural—in place of the present composite one. With the Staff as it is now, however, the existing arrangement works too well to be altered.

108. On some subjects, *e.g.*, pruning and manuring, experiments have been many and long continued. The results, expressed lengthily and scientifically, are dispersed over several Annual Reports. We suggest Occasional Pamphlets, described in paragraph 202 (*c*), should now be written to make the applications of the results readily available to planters.

109. As Borbhetta experiments are on relatively young tea, the projected experiments on estates in different districts, should be arranged to provide information, in part, from old tea.

110. Planters' questions are unceasing and this Branch has the very proper ambition of answering all of them by facts from experiments. We see a danger of over-dispersion of effort and believe, for instance, the desirability of continuing studies in soil nitrogen and soil acidity should be reconsidered.

111. A few years ago, new methods of plot lay-out and statistical analysis were very rapidly developed. For a time Tocklai did not make use of the new methods but the Chemical Branch has now taken them up with great thoroughness and success, having indeed, introduced certain interesting special applications of them to meet the particular circumstances of its work.

112. The general policy of the Branch should clearly be to test in separate localities, the main results of its agricultural experiments at Borbhetta and Tulsipara; and then to impress the finally approved practical applications upon the planting

community. Refinements and relatively small extensions of the present main lines of work should be avoided.

113. Knowledge of practical problems and local conditions, with due attention to monetary aspects, is displayed in all the work of this Branch.

114. The experiments on organic matter in soils, including composting, now in contemplation, are in our view adequate treatment of this important subject.

115. We feel that the agricultural work of the Chemical Branch has been insufficiently appreciated by London, Calcutta and the industry generally. Lack of facilities for experiments in the various tea districts has laid open to criticism, and fair criticism, the greater part of the experimental results. Nevertheless, we say, this Branch has very substantially benefitted the industry and we are content to support ourselves by instancing :—

(*a*). The steady giving up of the very deep cultivation formerly practised.

(*b*). The substitution of pruning at about 18 to 22 inches for very deep and collar pruning.

(*c*). Systematic, intelligent use of fertiliser in place of systems based on prejudice and often extravagant.

These we hold are very important changes induced by experimental work but which having slowly come to be general in planting practice, are no longer associated with and accredited to their originators.

116. The ban on planting new areas of tea at Borbhetta is a very serious hindrance and should be removed at the earliest opportunity.

Bacteriological Branch (on soils).

117. The work, such as studies of nitrification in soils, was purely tentative and led to no decisive conclusions. Experience

in general has shown the great difficulty of dealing with problems of soil bacteriology even in specially equipped laboratories. For the past three years soil studies in the Branch have been in abeyance and we consider there is no case for their resumption.

The Value of the Work of the Scientific Department on Tea Growing.

118. We were expressly invited to report whether results are likely to be commensurate with the expenditure directed to research. Changes which we advocate in this Report will, we believe, add much to the fruitfulness of the Scientific Department. But we feel that the task entrusted to us, requires us to judge the value of past work the better to predict what may be expected in the future. To this difficult undertaking we have devoted constant and critical attention.

119. An informative though not decisive way of judging the services of the Department to tea growing, is to ask what would have been the condition of commercial practice if no research organisation had been set up to help it. Our reflections along this line, so far as they signify, completely vindicate past expenditure on research.

120. Our systematic enquiry has had a double form. We have frankly asked planters and other members of the industry for their opinions of the value of past research : and we have studied the condition of the industry and the past and current work of the Department at first hand. The industry, and especially the planting community, undoubtedly appreciate what the Department has done and credit it with substantial helpfulness in many directions.

121. We ourselves judge the Department first as a scientific institution and find in its achievements sound warrant for the money spent on it. Next we take its influence on tea growing practice, leaving tea making to the final paragraph of Section VII. We see valuable assistance in many varied directions. In primary agricultural matters such as soil problems, manuring,

soil cultivation and pruning, improvements in general practice from research have resulted in very great monetary benefits. It would be impracticable to make a full list of all the aids research has produced to tea growing in North-East India. But we, representing a diversity of experience and interest, set it down as our firm opinion that what has been spent on the Scientific Department has been well spent. And further, we believe increased expenditure, conformably with the principles and specific ideas we have expounded, will be handsomely returned. The expenditure on research in all the main tea areas has received our close attention. We do not wish to speak in public of the outlay on, and circumstances of, research in other areas, but we are prepared to give the Indian Tea Association our reasons for feeling that the cost of scientific work in North-East India when judged in the light of the size and circumstances of the area, is such as to assure the Association of the reasonableness of their expenditure.

SECTION V.

THE PROBLEM OF QUALITY.

122. In tea-tasting, quality is one of those undefined components, body, aroma, etc., being others, by which the market value of a tea is determined. But in tea growing circles and for crop products at large, the word quality is used to include all the characteristics or components which govern market value. We have found it desirable in our discussions to use the word in this general sense and have so used it throughout this Report.

123. The problems connected with quality have been the most difficult part of the scientific side of our work. They are, firstly, not at all easy to formulate as every section of our witnesses has found. They constitute the greatest challenge which the tea industry can make to science. We believe that in the economic future of the industry they will have a leading and, it may well be, the chief place.

124. Before quality problems can be scientifically investigated in a way appropriate to their importance, the following steps must be taken.

(A). To define quality for experimental purposes.

(B). To propound, for the investigator, the problems of quality with which the industry is confronted.

(C). To make decisions on certain aspects of experimentation such as the problem of sampling and the range of investigation which is possible with the scientific facilities available.

We devote this Section to these three steps, (*viz.*, A in paragraphs 134 to 138; B in paragraphs 139 to 140; and C in paragraphs 141 to 144). Then in Section VI we examine all the lines of study by which the quality problems of the industry might be attacked, indicating those we believe to be the best to commence with. In Section VII we briefly review the research on quality already carried out by the Scientific Department.

The Meaning of Quality.

125. Quality, at the present time, can only be defined as a conception, more of art than of intellect, of which tea tasters are the repository and by the aid of which teas are valued in commerce. How they apply this conception to a tea is well-known. Their judgment is decisively expressed by a price and they explain it by reporting on certain components of quality such as pungency, colour of the liquor, etc. In reporting on these components they make use of a great number of descriptive words and phrases. The list of components referred to is not necessarily the same in reports by the same taster on different teas or by different tasters on the same tea. Of the relative monetary importance of the individual components of quality nothing is said. This, indeed, for one and the same tea, may not be the same in the judgment of different tasters who may have personal predilections arising from the particular market demands they have in mind. The descriptive words and phrases used in connection with the several components of quality exceed seventy in number. Some are synonyms, some are variably used by different tasters and some are, at any rate outside tasting circles, obscure in meaning.

A Dangerous Situation.

126. Discussions with all sections of the tea industry, in which we have been most cordially assisted by the tasters themselves, convince us that present methods of specifying tea quality are in some respects commercially undesirable while for science they completely rule out constructive investigation. They create, therefore, a dangerous situation. It is our chief concern here to propose measures by which this obstacle to research can be removed but we think it desirable to review first the commercial aspects of this question.

127. The brokers' report is passed on to the planter. If the price be unexpectedly low he naturally wishes to find out the particular characteristics in which his tea was faulty. He would then, of course, connect the faults with the circumstances of the

leaf or the manufacturing and take immediate steps to improve his quality. But in many such cases the report is obscure and, indeed, virtually meaningless, leaving the planter entirely without guidance. We think it of the greatest importance to the industry that the brokers' report should not be limited, as in effect and usefulness it sometimes is, to a cash valuation. He should give such information as to the faults and merits of the teas on the market ruling as to guide the planter in his policy. This he cannot do unless he speaks in terms as to which the planter has no doubt.

128. Terminological obscurity, amounting almost to mystery, in dealing with tea quality, may come to have serious marketing implications especially for the higher quality teas. Present day consumers dislike buying mysteries and in commodity markets generally there is a strong demand for declared and regularly maintained grades. Producers of apples, bacon, eggs, prunes and many other familiar commodities are making strong efforts to meet this demand. Now the subtleness of tea quality makes grading, of the kind easily developed with ordinary food products, unattainable with tea. We doubt, however, whether the tea industry can safely continue to do nothing to change the system by which quality is judged and specified. That almost all tea reaches the consumer as a blend does not, in our view, weaken the arguments here used. The desirability of change in commercial practice is not, however, our direct concern. We turn, therefore, to the scientific need for a new specification of quality which is a matter of the first importance and of the greatest urgency.

Scientific Requirements.

129. There are two reasons why present methods of specifying quality, when used in connection with scientific investigation, are an insurmountable obstacle to progress. Only the taster can say what the quality of a tea is, for the tea trade will listen to no one else. Thus he becomes a key-member of the scientific staff in any experiment on quality, *e.g.*, a study of the

effect of different manurial treatments on quality. But taster A may differ from taster B; and actual test has sometimes given whimsical proof of this. Here is the first difficulty. Now different plots receiving the same manurial treatment in an experiment may, for instance, give very different yields because of soil variations. But these differences are in a form which science, by the principles of statistics, can safely and appropriately deal with. Differences in brokers' verdicts, however, in their present form, are a phenomenon with which science cannot deal. We have explained in paragraph 125 how easy it may be to account for at any rate some of the differences between one broker and another. This explanation, of course, does nothing to remove the obstacle to scientific study.

130. The second reason why current ways of specifying quality impede investigation, is even more serious than the first. It must always be an aim of science to connect cause and effect. Let us take, for illustration, an experiment on the effects of nitrogen, potash and phosphoric acid on quality. It will be necessary to apply varying doses of these three substances and various combinations, *e.g.*, nitrogen only, nitrogen and potash together and so on. The planter naturally wishes to know how each substance, in light or heavy amount, and how each combination of two or three of the substances at a time, affects the quality of the made tea. The scientist can arrange an experiment to produce teas from every one of these manurial treatments, arranging, at the same time, a most careful check on the "statistical reliability" of the results. The whole, elaborate, experiment must now be consummated by the tasters' deciding on the quality of the tea from every plot. With present practice the only information in a tasters' report which has for all teas a constant purport, is the price. But price does not meet scientific requirements. It is essential to know how each manurial treatment has affected each component of tea quality—briskness, the colour of the liquor, the body. Moreover, this information must be given under the same headings and in the same form for all teas from all experiments. What is required is summed up by saying

that a uniform and analytical system for specification of quality must be evolved. The uselessness and even danger of a specification in which price is the only significant data is at once apparent. Two teas from an experiment may be worth the same price one being outstanding in one characteristic and one in another. Price would thus not help in connecting individual causes with individual effects in the way which has been explained to be necessary.

131. We attach the greatest importance to the analytical specification of quality. Without it, proper scientific study will be impossible; for lack of it a very great proportion of past experiments on quality has, in our view, been made utterly worthless and a waste of time.

132. It must not be supposed that research workers aided by certain others in the tea industry, have either ignored or failed to grapple with this difficulty. The great efforts to secure the tasters' concurrence in the use of a standard glossary, made by the Association's Scientific Department, are well-known. Moreover, the difficulties of assessing quality of tea must not be forgotten. The practical criterion of tea quality is effect on the palate—a subtle thing. It is the inherent obscureness of quality which accounts for the obscureness of commercial practice in specifying it. Any reform in commercial practice would no doubt take a long time. But unless the tea industry speedily introduces an appropriate method of specifying quality for experimental purposes it will fail in duty to its scientific workers : and, we venture to point out, it will make the efforts of our Commission infructuous.

The Ultimate Scientific Specification of Quality.

133. Quality, however wide its range and obscure its nature, must depend on the properties of certain chemical substances present in the tea. These, in turn, are derived from certain chemical substances in the green leaf as a result of chemical and physical changes during manufacture. If these substances could be identified and if their effects on the palate could be fully worked out, it would be possible to make exact scientific defini-

ions of all grades and aspects of quality. It must be the research workers' ultimate ideal to identify these substances and their properties. But there must be no misunderstanding about the parts science and tea tasting are likely to play in buying and selling. If exact physical and chemical tests of quality can be devised they will be of great value in research and so lead to increased control over manufacture. On the market, however, large numbers of samples have to be valued in a short time. Rapidity is therefore essential and no chemical or physical test is likely to be of at all the same order of rapidity as tasting.

Proposals for Specifying Quality for Experimental Purposes.

134. What is meant by analytical specification of quality and why this is essential for scientific work, has been explained in paragraph 130. The Commission has discussed this matter with both London and Calcutta tasters and has their warm concurrence in the principles of the proposals which are now to be made (paragraph 138 below).

135. We should be concealing an aspect of much significance if we did not record that evidence given to us reveals a sharp difference of tasters' opinion between London and Calcutta upon certain questions connected with experimental teas. We have considered many reasons which help to account for this difference but do not think it necessary to give them here. In our opinion, if the expert bodies in London and Calcutta both assist Tocklai in experiments on quality, difference of opinion between them will be by degrees removed, and, indeed, unless fundamental differences can be removed, the tea industry of North-East India will have to admit the unsatisfactoriness of a situation of which the crippling of scientific work will not be the only bad feature.

136. Shortly after discussing quality specification with London brokers, a member of the Commission visited Ceylon. He found, there, already in working, a system for judging teas from experiments. It proved in all essentials the same as that which had shaped itself in the London discussions. Ceylon, we

venture to say has made here a most important advance in bringing quality under critical study. Their initial success is an incentive to other countries and their experience will be a valuable guide. The Commission is greatly indebted to the Board of Management, the Director and the Staff of the Tea Research Institute for the kindness with which a complete explanation of the system was given.

137. In the Nederlands Indies, as is well-known, tea is sold by entirely different methods from those used by British interests. Correspondingly, valuation reports on teas are different. They are simple and employ a strictly limited terminology. Their form might well be studied in carrying out the proposals we make for specifying quality. Further, if as we hope, conjoint effort in research by the various tea countries becomes possible, the nearest practicable approach to a single system for specifying quality in experimental teas will be desirable. We realise that objection may be raised to the idea of a single system (for experimental teas only) for use with teas of so strongly marked individuality as those of North-East India, South India, Ceylon and the Nederlands Indies. It must be remembered, however, that if any country's results are to give any assistance in others, all must be upon a common basis.

138. We propose the following arrangements for judging and specifying the quality of experimental teas.

(*a*). That a limited number, preferably not more that six, components or characteristics of quality, be always reported on. These should be the characteristics which best combine commercial importance and suitability for experimental purposes. Appearance, if included, would need careful specification. In illustration of this, it may be mentioned that an otherwise ordinary tea may be improved in appearance by the old Assam practice, now to be seen in Java, of taking off tip from a bulk, on flannel, and using it to make special parcels.

(*b*). That in reporting on each characteristic one and the same system be used for indicating level of excellence. Several systems are possible. For instance, the taster using his general experience, might award marks for each characteristic out of a total of 10. One objection to this would be the inevitable tendency of some readers of reports to look on the total marks of any tea, for the selected characteristics, as indicating its all round merit and relative market value. The system we favour is a comparative-value one. In any experiment, one tea, usually that from the control plots should be taken as the standard of quality. Then for each characteristic in turn, every other tea should be reported as equal to, better than, or worse than, the control. There might be 3, 4, or even five degrees above and below equality with the standard, each denoted by a single, suitable phrase, *e.g.*, better (or worse), much better, and very much better than standard. Upon this and all other aspects of the system the example and experience of Ceylon will be of the greatest value.

(*c*). That personal bias and the specific requirements of particular markets be prevented from affecting reports by arranging for a panel of three or four brokers to make a single, joint, report. Each broker would prepare his own report, and the panel would then assemble and make its joint report. There should be one such panel in London and one in Calcutta and each should send its reports to Tocklai and to the other panel. The samples from an experiment should be sent to the tasters under serial numbers or other suitable marks, the identity of the standard being disclosed. The key to the serial

numbers should be given to the tasters immediately after their report is completed to enable them to know the value of the experiment before their recollection of the exact characteristics of the teas has ceased to be fresh. Our evidence encourages us to believe that brokers will be prepared to play their part in such a system and will, moreover, take a keen interest in the results of the experiments. We have carefully considered the alternative to joint report by a panel of brokers, *i.e.*, individual reports. It has the advantage of securing repetition of result and so permitting of statistical analysis of brokers' opinions. While we adhere to our preference for a panel we point out that no amount of reasoning can decide between the two systems. Trial alone will show which is the better for scientific purposes.

(*d*). Careful preparation, involving many preliminary experiments and the closest collaboration between the brokers and the Scientific Department, will be needed to launch this system. One important point to decide will be the number of samples and the size of each, to be sent to the brokers from each "treatment" in any experiment. The question of water for tasting will also arise. In commerce it is always insisted that most careful allowance be made for local water peculiarities in blending. Whether corresponding allowance is made in tasting straight teas in, it may be London, Melbourne and Calcutta, seems uncertain. One body of witnesses explained that the water supply in one well-known place, interested in tea, varied with the seasons of the year. For experimental purposes careful provision for tasting water must be made. Possibly a plan worth considering for uniformity

in experiments would be that adopted by one large commercial house which uses distilled water.

(*e*). One of the most difficult matters to settle is the number of different teas, from any one experiment, which tasters can be expected to judge with certainty. The research worker might well desire to have, in, let us say, a manurial experiment, eight treatments and a control (*i.e.*, no manure). This would give nine lots of tea. We learn that it is difficult for the taster to discriminate the differences among six different teas, at most, when these are as close in quality as they have usually been in past manurial and other experiments. It must be remembered also that plot experiments are "replicated", *e.g.*, several plots are laid down for each of the treatments. The fact gives rise to yet further questions which will have to be dealt with in the preliminary investigations.

Having made these proposals for specifying quality in a manner appropriate to the needs of scientific study we turn next to consider the problems involving quality, which the industry presents to science.

The Problems of Quality.

139. In Section II we have reviewed the main economic problems of the tea industry including those in which quality is primarily concerned : in Appendix I are summarised the views on quality problems contained in replies to our questionnaire. These latter show a general uneasiness about quality, which arises mostly from its uncertain connection with manufacture. They display, too, a general desire to improve quality but not according to any thought-out policy. Such specific suggestions as they contain are for getting more knowledge about the proper regulation of and the effects of, the separate stages of manufacture, especially withering.

140. We have been forced to conclude that general ignorance (a word we take from one of our witnesses) is the basal problem of quality with which the industry is confronted. It must be dealt with by seeking for more knowledge. But the possible field for scientific study of tea quality is literally unbounded and it is thus essential to select certain lines of enquiry. After careful study, including discussion with many witnesses, we suggest the lines set out below :—

(*a*). The building up of a suitable analytical method of specifying quality, as already explained (paragraph 138).

(*b*). A survey of conditions in representative commercial factories in North-East India to ascertain how wide are the customary variations in temperature and other factors and in the condition of the raw material, both from time to time in one factory and as between different factories.

(*c*). Well planned trials, with the necessary ancillary experiments, with the object of finding out how variations in manuring, soil character, pruning, etc., and in the separate stages of manufacture, affect the individual components or characteristics of quality.

(*d*). Investigations with the object of discovering the chemical substances in the leaf, the chemical and physical changes they undergo during the successive stages of manufacture and the ways in which these substances and changes influence the market value and the components of quality of tea. This, the fundamental enquiry will, in measure as it succeeds, yield the master knowledge of tea quality.

(*e*). Jat selection, by which quality (as well as yield) might possibly be improved but which can proceed only as means are devised for testing quality with small amounts of leaf.

(*f*). The study of commercial and economic aspects of quality, including problems of the kind discussed in Section II.

We expand these proposals for investigations in Section VI. It is naturally in the forefront of our considerations that no method of controlling or improving quality is of any final or commercial value unless it is profitable, though it may yet be of scientific importance.

Some General Aspects of Research on Quality.

141. Our discussions have convinced us that in some sections of the industry the magnitude and difficult nature of a proper study of tea quality, are imperfectly realised. Partly for this reason, but also as part of our own consideration of the quality problem, we therefore briefly discuss here two general aspects of research on quality. One is the problem of sampling, the other the range of possible experiments.

142. The "problem of sampling" runs all through every kind of research in which material and procedure are not perfectly constant. Suppose, for example, the effects of the various stages of manufacture on quality are to be studied. To give as much constancy as possible, let it be assumed that the green leaf can be obtained from the following closely specified conditions : a block of one acre of land; the bushes on it all to be of exactly the same jat and of the same age; cultivation, manuring, plucking, and pruning to be the same all over the block. Now the soil will certainly not be uniform over any acre and thus the green leaf from different bushes cannot be entirely uniform. The whole bulk of material from this acre could be manufactured, but a chemist could not analyse it all. He would have to draw small samples from it for analysis. His results would differ from sample to sample. By analysing a great number of samples from the bulk he could find out the "range of variation" within the bulk and by familiar statistical methods he could decide how many samples and the size of sample it would be necessary to use, to get an average figure properly representative of the

whole bulk and to a stated degree of accuracy. It is essential thus to study the "sampling error" at every stage. This study makes it possible to test the "reliability of result". Without ascertaining this reliability, the greatest perfection in the actual procedure of weighing, analysis, etc., is of no avail, and dangerous, false, inferences may be drawn. An essential principle for calculating reliability of result is repetition of observations, *e.g.*, several sub-samples from the bulk in the case under discussion. It is this principle which necessitates having several plots for each different kind of manure in a trial of the effects of different manures on yield. Correspondingly, when the effects on quality of the various stages of manufacture have to be studied, the chemist will have to draw several samples of the material after withering, after rolling, etc. Moreover, any one stage, *e.g.*, firing , cannot be carried out in precisely the same way on different days. How much the day-to-day variations may affect the made tea can only be found out by repeating the firing (or other process) a number of times. Thus the sampling problem must be a subject of special study at every stage as a preliminary to systematic investigation of the effects of that stage on quality. These considerations show that every plan of investigation implies, in practice, a series of "repetitions" by which the investigation is greatly enlarged beyond the skeleton form of the proposals written out for it. Research workers have to deal with the problem of sampling in every experiment. The layman must understand its general nature and the principles by which it is dealt with if he is to appreciate the requirements of accurate experimentation.

The Vast Field of Research on Quality.

143. The magnitude of the field of research opened up by questions relating to quality in tea is impressive to the point of dismay. It is obviously essential for the research worker to examine the scope of possible enquiry with care. We think it highly desirable also, that those who pay for or are otherwise interested in tea research should give careful thought to this matter. It is for them we contribute the outline considerations which now follow.

144. To understand the quality problem from the point of view of the investigator it is necessary to make a complete theoretical analysis of the factors governing quality. These constitute two groups associated respectively with the raw material (green leaf) and with the stages of manufacture and may be thus set out : (with sufficient completeness to illustrate the principles involved).

Green Leaf.	*Manufacture.*
1. Jat.	1. Withering.
2. Inherent physiological condition of bush.	2. Rolling.
3. Age of bush.	3. Fermenting.
4. State as affected by spacing, pruning.	4. Firing.
5. Nature of plucking.	5. Storage and transport in India. Sea transport. Warehousing.
6. Locality (altitude, etc.).	
7. Soil.	
8. Cultivation.	
9. Disease.	
10. Time of year.	

The finally made tea is influenced by each one of these factors and the effect of any one factor is partly controlled by the effects of the other factors preceding it in action. Thus the influence of firing depends upon, among other things, the effect that manuring has had on the leaf, while this, in turn, is influenced by the jat of tea concerned. For every factor in the list above a considerable range of variation is possible. Many different jats could be tried; at least six different kinds of manuring could be described as of practical interest; any one of the factors (*i.e.*, stages) in manufacture could be tried in several different forms or degrees, *e.g.*, for firing two different temperatures and two different time exposures. Thus for a theoretically full study of quality, suitable variations or degrees of every factor should be tried in combination with those of every other, each set of combinations producing

a different "experimental tea". There are 15 factors mentioned in the list above. If only 2 variations of each were possible, the total number of combinations of factors, *i.e.*, the total number of separate tea-makings would be $2 \times 2 \times 2$——15 times = 32,768. With an average of three variations for each factor the number of tea makings would be 14,348,907. To bring the possibilities back to manageable numbers, let it be assumed that 5 factors can be selected from the 15 as being the only ones likely to matter much—a big assumption. Then taking the number of variations of each factor as 2, the number of necessary tea makings will be 32; for 3 variations per factor the number will be 243. These reduced though still big numbers do not, however, disclose the magnitude of the experimental work involved. As explained in Section 21 (above) any one tea making (*i.e.*, combination of factors) would have to be subject to repetition to ensure reliability of results. At least 4 repetitions, multiplying correspondingly the above numbers of experimental tea makings, might well be required. If chemical analyses of raw material were made at the beginning and end of each stage of manufacture, the number of samples to be analysed would be several times multiplied again. This would bring numbers once more to levels of impracticability. It will be realised that this account does no more than mention the experiments which might conceivably and not unreasonably be undertaken if resources allowed. The carrying out of some stages, especially for instance the chemical analysis of the leaf and the products derived from it, would in practice be very lengthy and intricate. The conclusion we wish to make clear is that great care must be shown in deciding what experiments to make on quality; that only a few can be carried on at one time; and that for these, ample resources and a considerable span of time are necessary.

SECTION VI.

THE FIELD OF RESEARCH IN TEA QUALITY AND MANUFACTURE.

145. It has been said that tea quality and manufacture are "no job for the scientist" but require "constant trial and error work by some one with an inventive mind and a gift for cooking". We do not agree. As will be seen in later passages, we favour empirical methods, *i.e.*, a carefully planned form of trial and error for some investigations on quality and manufacture, but we are convinced it is by scientific experimentation alone that fundamental knowledge of these two difficult subjects can be gained. Moreover, fundamental knowledge and not occasional small discoveries by trial and error is essential to make clear the nature of quality and to give control and ensure improvement in manufacture.

146. We suggested in paragraph 140 the main lines of enquiry into quality and manufacture and we proceed now to expand these. In doing this we avoid detail, for many parts of this subject are undeveloped and final choice of lines of enquiry will have to be made from time to time by the investigators themselves as work proceeds. The factors affecting quality of tea fall into two groups : those connected with tea growing; and those connected with tea making. These two groups are, of course, intricately connected. For instance, weather affects fineness of plucking; this in turn probably affects withering, which in turn is believed to affect all the other stages of tea making. The two groups of factors are now to be separately discussed.

Factors of Tea Growing which Affect Quality.

147. As explained in Section III the yield of tea is influenced by internal factors (factors of the plant itself) and external factors (factors of the environment) and the same is true of quality. It follows that the field of research on tea quality is exactly the same as for tea growing but since experiments on quality are much more difficult than those on yield the number

of factors studied must be limited. Taking internal factors (the plant itself) first, two matters require attention, namely, jat selection and physiology of withering.

Jat and Quality.

148. The possibility that differences among individual plants greatly influence quality is not very clearly realised, we feel, by the planting community. In practice leaf mainly from one jat may occupy the factory one day and that mainly from another jat on the next day. Some fluctuations in the quality of the made tea may be thus explicable. Or on any one day leaf from two or even more jats may be mixed and used in the factory. Circumstances when leaf from only one jat is manufactured at a time must be examined. As explained in Section III a jat consists of a considerable number of different botanical types. Consequently in successive pluckings from an area of one jat, the proportionate amounts of leaf from the various botanical types, cannot be constant. For this further reason then, quality fluctuations in made tea may arise. It seems reasonable to suggest that more uniform jats (the clones of paragraph 36) would result in greater uniformity in the finished tea.

Plant Breeding and Quality.

149. These considerations suggest the same field for single bush selection for high quality as has been considered for high yield (see Section III). In fact yield and quality must be dealt with together in plant breeding. The immediate difficulty is that no small-scale tests for tea quality have yet been devised. This is one of the reasons for trying to evolve laboratory-scale tea making equipment as explained in paragraph 158. The later stages of breeding would require an intermediate-size manufacturing plant and for this the present Tocklai factory would suffice. It is quite likely that knowledge gained from the physiology of withering and the chemistry of leaf and tea—subjects we commend elsewhere for study—will provide aids to the plant breeder in selecting for quality. It may be asked whether plant breeding should be started until appropriate small-scale tests for quality

are available. We are strongly in favour of beginning at once because of the slowness of plant breeding with a perennial crop like tea.

Physiology of Withering.

150. Withering may ultimately disappear in some districts from a considerable part of the tea-making year but is not likely to be entirely given up. Meantime it seems generally regarded as the most influential stage of manufacture. It is not to be looked on as simply the drying out of inanimate material, for at first it represents physiological activity, especially respiration and transpiration, of living tissue and we commend a physiological study of it. This will involve associated work on histology, *i.e.*, the minute anatomical structure of the bud, leaf, and stem of the tea. A wide range of enquiry should be embraced including variations in age of shoot, the proportions by weight of bud, leaves and stalk, relative rates of loss of water of these parts, jat differences, manurial effects and changes in external conditions such as temperature. The undertaking must be in the hands of a highly trained physiologist.

Environment and Quality.

151. Leaving the plant we turn to the environment which by affecting growth affects the composition and structure of the leaf and so the quality of the tea made from it. It is obvious that, broadly speaking, quality should be examined on the leaf from all plot experiments which deal with the effects of environment on yield, namely, manuring, pruning, plucking, soil cultivation, etc. That is to say, yield and quality should both be dealt with in all experiments of this kind. Some of the environmental factors are, however, specially important and we therefore consider them all in turn.

Soil Type and Quality.

152. Soil type is generally believed to have so great an effect on quality, that no amount of skill in manuring, pruning,

and plucking can avail to do more than slightly modify its influences. That is the soil type on any estate is believed to set a sharp upper limit to the quality of tea which can be made on that estate. *It would clearly be valuable if for every estate the upper limit of quality set by its soil type could be determined.* To do this would involve a correlation of soil type and quality, a most interesting undertaking but for which we are sure resources do not, at present, exist. Possibly in time the proposed Advisory Officers might be able to take some steps towards testing and more closely defining common general beliefs as to the relation between local soils and tea quality. Moreover, partial chemical tests of quality may be evolved from the fundamental chemistry of tea and thus may make the correlation of soil type and quality a practical undertaking.

Manuring and Quality.

153. The lines suggested in connection with manuring and yield in Section III indicate the scope required here and the same set of experiments should, of course, be used. They will make it possible to say whether nitrogen in an organic form is essential to high quality and to answer other questions of this type which have agitated certain sections of the tea industry and particularly London Houses.

Climate and Quality.

154. Climate like soil is believed to set a sharp upper limit to quality. As in the case of yield we do not favour a survey of this matter. Statistical study in the form of a correlation of rainfall and quality or altitude and quality would be possible, quality being taken for this purpose as price. Estate records going back over many years would furnish material. We do not, however, think such an enquiry worthwhile at present. Shade partly controls certain climatic factors and our recommendations on the study of shade in relation to yield apply in principle to quality. (See paragraph 52).

Diseases, Pests and Quality.

155. Any disturbance to growth by pest or disease is bound to affect leaf and therefore made tea, but the practical situation in North-East India is such as to call for general observations and not specific experiment upon this point. The idea that "green fly" induces high quality might be taken up by the local Advisory Officers as a matter of interest.

Plucking and Quality.

156. Soil cultivation though obviously not entirely unconnected with quality calls for no immediate investigation at present. Pruning, the influence of which on quality is in some circumstances highly important, would involve experiments too extensive to take up until manuring has been dealt with. In the case of plucking, however, the study of quality should be made on material from the experimental plots in which plucking is studied from the point of view of yield. If, however, pressure of work compels a limitation of quality study on the produce of experimental plots, preference should be given to the effects of manuring over those of plucking.

Factors of Tea Making which Affect Quality.

157. We take up now the outstandingly difficult part of our whole task. Of the importance of studying tea making and its effects on quality we are wholly convinced but we are forced to realise that our investigations on it though generously assisted by the tea industry and especially by the carefully thought out opinions of the Staff at Tocklai, do not carry us beyond broad initial proposals. Indeed for anyone to go beyond such proposals would, at present, be impossible and it is by the investigators themselves as their experience grows that the lines of research will have to be finally decided. We suggest that the subjects to be attended to are as in the list following and we discuss them one by one in ensuing paragraphs.

(*a*). Devising a very small-scale, *i.e.*, laboratory-scale manufacturing plant.

(*b*). Improving the existing small factory plant at Tocklai for use with plot experiments.

(*c*). Surveying the current practices of tea making in the factories of North-East India.

(*d*). Devising a small-scale factory plant for widely ranging experiments on all the processes of tea manufacture.

(*e*) Experiments with this small plant on the processes of tea manufacture and especially on withering.

(*f*). Arranging to check results obtained in small-scale experiments on manufacture and quality by means of trials in commercial factories.

(*g*). Designing and testing new machinery.

(*h*). Fundamental chemistry of tea.

(*j*). Bacteriology of tea making.

(*a*). *Laboratory-Scale Manufacture.*

158. As already explained, jat selection ultimately depends on the possibility of testing quality on such a scale that the leaf from a single bush can be dealt with. This is the first reason which makes laboratory-scale manufacture necessary. It would, further, be very useful for preliminary experiments on the influences of various factors in tea making and would afford guidance for the construction of the small-scale plant for manufacturing which is dealt with in paragraph 163. Moreover, a laboratory-scale plant might be required to provide material for a study of the chemistry of manufacture. It should not be difficult to produce the required apparatus save in the case of the rollers. One of the great advantages of work on this very small scale would be the relative cheapness of the equipment and the ease with which it could be constantly altered and adapted to experimental needs.

159. The criticism has been made that a small-scale plant cannot produce normal "tea", being limited to a tea-like substance. This criticism has made us anxious concerning the possibility of experimentation on the lines it seems right to us to suggest. After careful enquiry we are not prepared to accept the criticism. Our belief is that the Scientific Department with its admittedly imperfect small plant has produced tea and tea which commerce will accept. It is possible that the very small laboratory-scale plant we have in mind may not produce commercial tea. If it do not there will be two interesting problems to deal with. First, why cannot commercial tea be made in diminutive amounts on a very small-scale plant? Next, how can the products of a very small plant be correlated with commercial tea in such a way as to be used to interpret the results of experiments?

(*b*). *Improving the Existing Manufacturing Plant at Tocklai.*

160. The much criticised factory at Tocklai has been used for a remarkable number and diversity of experiments. These have been limited in range and effectiveness. There is not the slightest doubt that the present equipment is quite useless for the systematic investigation of variations in manufacturing processes and their effects on quality of made tea. Nevertheless, the equipment can be continued in use, for the manufacture of leaf from plot experiments. Certain improvements are necessary to get the best value from it but these should not be undertaken until further experience has been gained. At present the chief difficulty is that there are only two rollers and these are not alike. Consequently in plot experiments with eight different treatments, the eight lots of tea have to be rolled in four pairs, or for six treatments there would be three pairs. As atmospheric temperature rises during the day, rolling temperature naturally shows a steady rise, with corresponding decline in quality. Allowances are made for this by an appropriate statistical arrangement. To have four rollers, all alike, would get over this but the alteration is not immediately required.

(c). Survey of Tea Making in North-East India.

161. We ventured to say in paragraph 140 that ignorance was the only clear basic problem connected with manufacture and quality. Propounding this problem more fully, we should say that in tea factories, generally, there is a great desire to know : the upper, lower, and in the circumstances of each factory the optimum values of time, temperature and other physical conditions at every stage of manufacture; how variations in each of these conditions affect quality; how, correspondingly, the condition of the leaf, *e.g.*, water content or temperature, influences results at each stage of manufacture; and finally by what means human judgment by sight and touch may be displaced so as to give a more reliable control over tea making. Knowledge of this kind can only be obtained by experiments on each stage of manufacture. But to decide what form and range of variation of temperature and all the other factors to study will require great care, for the experiments will be extremely difficult and it will be possible to carry out only a relatively small number. Now a good guide would be to ascertain the variations in conditions found in commercial factories. We therefore propose a survey by resident Advisory Officers in representative factories willing to give facilities for this.

162. Besides being useful in planning experiments, the survey should have two other advantages. First, it would show the condition of the industry in North-East India as a whole in respect of manufacture. For example, it would show the methods relied on for deciding when withering is complete. In some factories the method is to judge by sight and touch. In a few the water content of the leaf is determined. Information will also be obtained about the extent to which it is sought to control other processes by accurate observations, for example, the use of thermometers in firing machines. The fact that recording instruments have been fitted does not prove that they are in order or that they are used or that their use is advantageous. Secondly, the survey might throw light on the frequent complaint that a factory is inconstant, *i.e.*, the same procedure does not on two

successive or near days give the same result. A corresponding situation is that two factories side by side frequently get different results when on general grounds similarity should be expected. Several explanations of these occurrences are possible. For example, differences in jat or state of flush or method of plucking might be responsible and bacterial action might play a part. General opinion points to another possibility namely, that great variations occur from day to day, or in any one day, in every process of manufacture and occasionally a chance combination of extreme variations in each process tends to an extreme result, either favourable or unfavourable. Characteristic examples would be :—the leaf from some parts of the house being over withered, that from other parts, taken off the racks at the same time, being incompletely withered; the degree of cooling of leaf during transfer from the roller to the sifting machine and during sifting not being always the same; fermenting floors of different material withdrawing unequal amounts of heat from the fermenting leaf because of differences in their specific heat and conductivity. It should be the object of the survey to compare one factory with another and to determine the space and time variations in every process in single factories. Control over manufacture by which, with reasonably constant leaf, constancy could be ensured in made tea is what the average estate appears to regard as one of its greatest needs. It is evident too that fairly high constancy of operation will be essential in the experimental equipment we have recommended. Thus the circumstances affecting and the possibilities of achieving high constancy of work, may be specified as one of the principal objects of this survey.

(*d*). *Small-Scale Factory Plant for Experimentation.*

163. To investigate the individual stages of tea making, special manufacturing plant will be necessary. Any large scale factory would be, in our view, useless for experimentation in the proper sense of that word, for it could not be rapidly and completely altered. It is chiefly for that reason that in Section IX we do not recommend a full size factory for Tocklai. In our view there is needed for experimental purposes a factory of about the size of the present one at Tocklai, *i.e.*, with rollers taking a

charge of about twenty to fifty pounds of leaf. It will be a long, somewhat costly undertaking, involving much trial and great mechanical ingenuity, to design and construct this experimental plant. In this work the makers could give great assistance and would thereby advantage themselves, for from these experiments fresh developments in machinery may well come. Experience gained in the experiments with the laboratory-scale plant of paragraph 158 will also be of value here. The aim must be to construct equipment which will allow every process of tea making to be varied over a very wide range so that the effect on quality of all kinds of variations in manufacture may be discovered.

(*e*). *Experimentation on the Individual Manufacturing Processes.*

164. We have dealt, in the opening passage of paragraph 161, with the objects of investigations on manufacturing processes and with the necessary equipment in paragraph 163. We do not attempt to specify details of these experiments but record certain general views. Withering should be made the first subject of investigation since all other stages of manufacture are believed to depend on this one. We have in paragraph 150 recommended a separate investigation of withering as a problem in plant physiology.

165. We have found many planters, especially those with engineering knowledge, possessed of a strong general feeling that the use of machinery for tea making is in a sadly undeveloped state. They feel a paralysis has laid hold of it and that in place of the new ideas which abound in the use of machinery in industry at large there has in tea machinery been for years no greater ambition than to increase the mechanical efficiency of customary types. We ourselves agree with this view though the introduction of processes supplementary to rolling shows that some progress is being made. Difficulties in the way of progress are evident. The situation is similar to that of agricultural machinery in a small country like Great Britain which, in contrast with the North American continent, cannot offer the manufacturer the inducement of a large demand. Or the situation

may be differently illustrated by comparing either tea machinery, or agricultural machinery in Great Britain, with motor cars. Whereas comparatively trivial changes may serve to sell new models in cars, year after year, agricultural and tea machinery has a very long life. Thus the incentive to the maker to produce new models is small. We think, however, that the undeveloped state of tea machinery and manufacture should be seriously considered by the industry in North-East India. A very substantial outlay in factory building and machinery may have to be faced during the next ten years and it would obviously be bad policy to make this outlay without the best engineering advice.

166. We are convinced great boldness should be shown in the Scientific Department's investigations of the individual stages of manufacture and no less boldness in the outlook of the makers of tea machinery. It might seem merely academic to suggest that temperature should be controlled during fermentation by having a fermenting chamber only one foot high with a water jacket and an air control; or equally so, to propose that rolling, including sifting and fermentation, should be one continuous process. That many notions of this kind should be entertained is a view to which any enquirer might well be led by the bold idea of Mr. G. S. Napier-Ford in overcoming the notorious difficulty of the process of withering by cutting it out entirely from manufacture. If any proof were needed of the contention that on the manufacturing side tea has been for many years tied tight by custom it is, we feel, to be found in what Mr. Napier-Ford has thus done.

167. It is not for us to attempt judgment on the ultimate utility of Mr. Napier-Ford's non-withering manufacture. Our enquiries in the different districts have revealed a great interest in non-withering and have shown the ludicrous kinds of criticism by which new ideas may be assailed. We hear, for instance, that when non-withering was first practised it brought a higher market price to the garden concerned but when a number of gardens began to practise it buyers dropped the price because the

supply of non-withered tea on the market was increasing. For this reason, it was argued, it was useless to go on with non-withering manufacture. We think the tea industry is under a great debt to Mr. Napier-Ford and the firm he represents for a stimulating idea.

(*f*). *Confirmation of Results in Large-Scale Factories.*

168. No experimental results concerning tea making can be recommended to estates unless confirmed by trial in commercial factories. Trials in the separate different districts are essential and we recommend the necessary procedure for this in paragraph 246.

(*g*). *Designing and Testing New Machinery.*

169. We have indulged with our witnesses and others in many discussions as to whether the tea industry, or alternatively the makers of machinery, should be responsible for developing new ideas and machines for tea making. The analogous question is frequently debated in connection with agricultural implements in Europe and America. In the matter of responsibility for, or probable means of, attaining original ideas, clear answers are impossible. Original ideas come from original minds and these occur in many walks of life. It is said that in the past planters have supplied virtually every new idea for the improvement of tea machinery, the makers having merely constructed the machines. We content ourselves by saying that one cardinal requirement is for the makers to assist Tocklai in every possible way both in devising their experimental tea making equipment and in carrying out experiments on it. Tocklai should, correspondingly, work as closely as possible with the makers.

170. We have consulted many witnesses about the advisability and possibility of trials of new machines before they came on to the market. It is evident that the industry might often be spared expense if an unquestionably reliable trial could be made of every new tea making machine before estates considered purchasing it. In some cases, we know, makers are prepared to erect a machine on the condition of purchase subject to satisfac-

tion but what they do in general falls far short of satisfying the need for trials. We have, however, been forced to recognise that the many difficulties of carrying out machinery trials make it impossible for us to recommend any plan for such trials in North-East India at the present time.

(*h*). *Fundamental Chemistry of Tea.*

171. A great amount of painstaking work on the chemistry of tea has been carried out by the Association's Scientific Department. The chemical study of tea and leaf has also been pursued in other areas. It is true that all this has so far provided the industry with no substantial applications. It is also true that the chemistry of crop and animal products, as a whole, is exceedingly difficult. We have carefully considered these facts and conclude that the study of the chemistry of tea should be resumed, leaf and material at successive stages of manufacture later coming under investigation. This study would require great facilities. A single chemist could not, for long, handle all the work nor, we think, could he be provided with suitable facilities including touch with other branches of science, save in some large European scientific centre. We refer again in paragraph 239 to this matter. Work of this kind is pre-eminently suitable for joint-action by the four tea areas of which we speak in Section XI. Before any decisive step is taken there should be consultation with the best obtainable chemical opinion and a full consideration of the value to future work of the scientific studies already made on tea in various places.

Bacteriology of Tea Making.

172. This part of the field of research, opened up almost entirely by the Association's own scientists, is so new as to require special treatment. There is little in experience with other crops to guide consideration of lines of enquiry suitable with tea. We have found it the most practicable plan to make our observations on past work in bacteriology (paragraph 184 to 192) also a review of the field of research.

SECTION VII.

PAST AND CURRENT RESEARCH ON TEA QUALITY AND MANUFACTURE.

General.

173. Direct investigation of manufacture has not received a share of attention proportionate to its industrial importance. There have been two reasons for this : ineffective arrangements for tasting experimental samples; and lack of equipment for this form of investigation.

174. The Scientific Department had for many years to sustain with inadequate support from the tea industry, a harassing struggle with tasters about their terms and methods. In the last few years it has made great progress on which it is to be congratulated. We believe our suggestions for further developments (paragraph 138) will prove advantageous to the judging of experimental teas.

175. Failure to develop the Tocklai factory to the condition required for direct study of tea making has been only in part due to limitation of money. Equipment on the lines we suggest in Section VI is urgently needed.

176. Although proper arrangements for judging experimental samples and facilities for manufacturing experiments were both lacking, a considerable number of small trials and experiments was made. These mostly led to no more than suggestive indications. They have, however, had their value in giving experience for more serious enquiry. Urgent desire for information about manufacture, in planting circles, virtually compelled the Department to take up some work on it despite lack of proper facilities.

177. Systematic surveys of factory conditions and practices (as carried out and not simply as they purport to be) have not been made. We think the Department is insufficiently cognisant of these matters. Observation must cover an adequate number of representative factories all over North-East India.

178. The frequent complaint (see Appendix I) that the Department has not checked ideas derived from experiments, by tests in factories in all the tea districts, is a true complaint. But it cannot fairly be pressed because of the smallness of the Staff. The case of E. C. Solution is the only serious one in point. Factory conditions (*e.g.*, porous fermenting floors) were not adequately found out.

179. The use of E. C. Solution is by no means universally condemned though its premature advocacy is rightly regretted. It must be made clear that the E. C. episode showed, among other things, either the incapacity of some factories to grasp simple instructions or their neglect in having them executed.

180. The decision to take up the fundamental chemistry of tea was, we think, premature, for more direct attacks on quality and manufacture had prior claims. Moreover, this chemical work when launched, was too ambitious. One must sympathise with a chemical laboratory which had no electric power until 1926 and in which until 1930 the gas supply was inadequate even for simple combustions. But these facts reinforce the contention that a premature start was made. When the work was decided on, it was inadequately planned. Instead of following a systematic, well selected, programme of work, a great diversity of problems, some extremely difficult, was pursued. The chemistry of leaf and of some intermediate substances was partly begun. At times, as internal evidence from the Annual Reports shows, the chemical Staff was overwhelmed by the fruits of its own labours and discontinuity of investigation ensued. The result of all this work, technically excellent, was of no immediate value to the industry but it will be of unquestionable value if the internationally planned research on made tea which we recommend, be taken in hand.

181. Quality studies in connection with the excellent plot work on yield in relation to manuring, etc., have been hampered by imperfect arrangements for tasting. Chemical work on the leaf (potash and phosphate content) and tea (total tannin, etc.) from these plots, still carried on, seems to us of doubtful value

for the heavily engaged Chemical Branch. Tannin content, etc., are proving to be correlated with tasters' verdicts but only within the limits of individual batches of teas, *i.e.*, from one and the same experiment.

182. Tocklai has been criticised for doing any experimental work with its small factory, even for making tea from manurial and other plots. This criticism is unsound, for smallness of machinery is not of itself universally objectionable.

183. It has been asserted that the Tocklai factory has never and can never make sound commercial tea. Evidence which we accept crushes this criticism.

Bacteriological Branch.

184. Arguments supporting the view that bacteria must play an unimportant part in manufacture in other tea areas do not prove the insignificance of these organisms in North-East India where low withers result in the spilling out of much leaf juice during rolling.

185. The main results claimed for the work of the Bacteriological Branch on tea quality and manufacture, may be thus stated :

(*a*). Certain pronounced taints in tea are caused by bacteria. These taints are not very common in commercial practice and only result from rather heavy bacterial infections. It is possible that a special characteristic taint may be caused by bacteria in all the tea made in a particular factory. This may not be positively objectionable and not strongly marked. It may become accepted by tasters as the type for which the factory is known.

(*b*). Soft liquors and dull infusions often occur in teas in general, especially in the rains. A number of things may cause them and bacterial action

is a common cause. A relatively light infection may be effective here.

(*c*). Both taints and also soft liquors and dull infusions, can be avoided by factory hygiene, *i.e.*, rigid attention to cleanliness. The Branch can discover the seats of infection in a factory and give advice for dealing with them. Even in the rains soft liquors and dull infusions need not occur.

(d). Full information has not yet been obtained as to the initial sources of infection. The bacteria proved to occur on tea leaf are not ordinarily objectionable but may be harmful in certain circumstances. The chemistry of bacterial action on tea has not been seriously studied, time for this difficult work not having yet been available.

(*e*). Moulds in a visible state (spores or hyphae) sometimes occur very abundantly on tea fresh from the driers. Should such a tea in transit or later rise above the normally safe percentage of moisture, the moulds may rapidly develop and make the tea "musty".

(*f*). It cannot yet be said whether or not bacteria normally play a part in tea making and bacteria which occur on green leaf may possibly play a regular part in fermentation.

(*g*). Yeasts may similarly be important.

(*h*). The reasons why a factory is not making good teas cannot be properly investigated, *e.g.*, as to the correctness of the rolling, unless it is first found out whether bacteria are responsible for any of the defects. On this ground bacteriology is indispensable in the application of science to the improvement of tea making.

186. To report on the work of the Branch we must examine the claims of these results to validity, and commercial importance. This is very difficult and we must make it clear that acceptance or rejection of these claims is not purely a matter for science. What is frequently of critical importance is the evidence as to whether or not certain blemishes are of common occurrence and substantial importance in industry; or whether certain conditions, proved to promote harmful bacterial action, do in fact frequently arise in commercial factories; or whether better factory hygiene has, where enforced, genuinely removed the defects for which it was adopted.

187. Result (*a*), as to taints seems well supported so far as marked taints are concerned. We think the right policy would be not to extend research on this matter for the present but to clinch the results by thoroughly applying them in commercial factories.

188. Result (*b*), as to soft liquors and dull infusions, has strong support from artificial inoculation experiments—an essential support. A relatively small number of factories has been dealt with by the Branch for these troubles and from them have come some emphatic written tributes and also verbal answers to our questions, assenting to the view that treatment for bacterial action has set matters right. Taking the very critical attitude our difficult task necessitates, we point out that some of the managers concerned may not have sound proof for what they aver and believe and we think yet more evidence is necessary. This matter is too novel and too important to be left in doubt and the industry must be convinced. Now it is obvious that the industry can and must convince itself. Let factories constantly troubled by defects attributed by the Branch to bacterial action, seek its help to overcome their difficulties. The industry must play its part here and so help forward this bacteriological work of which the inherent difficulties are very great.

189. The work from which results (*a*) and (*b*) of paragraph 185 have come—and it is the most important part of the work of this Branch—has necessarily been of the nature of trial and

error rather than systematic, scientific, research. There arises now, therefore, the question when and to what extent this empirical work should be carried to the stage of strict study of the scientific problems it involves. Among these problems are: identification of bacterial species concerned; the chemistry of bacterial action on tea at various stages; reactions of the bacteria concerned to temperature and other factors. Questions of this kind will have to be taken up in the interests of the tea industry if the claims set out in paragraph 185 (*a*), (*b*) and (*c*) prove to be fully substantiated. And if questions of this kind be taken up, the Branch must be free to pursue them in the customary scientific manner and not be subjected to the criticism that work of such a kind bears no obvious relation to the tea industry. But our view is that before the scientific approach is fully begun, the efficacy and range of application in North-East India of the main results so far claimed, must be emphatically demonstrated in commercial factories. Once the industry is persuaded of the wide importance of bacteriological measures it cannot withold generous support for further scientific work.

190. Concerning result (*d*)—initial sources of infection—we think the line of enquiry so far followed satisfies preliminary requirements. More thorough study would, however, be necessary to complete the understanding of bacterial influence on tea. Result (*e*)—moulds—raises novel and possibly most important questions. Their significance is so great that we think the present method of showing the presence of moulds on particles of tea should for safety be supplemented by direct detection of spores and mycelium. Complaints of tea "deteriorating" in transit or storage are fairly common and this matter gains great interest from them.

191. The Bacteriological Branch is all but the pioneer in studying bacteria in relation to tea and it has transmuted what was mere observations into a new field of research. Bacteriological work, especially when the results have to be expressed numerically, is well-known to require great caution. We feel that the Branch, in the rapidity of its advance, has been inclined

to burden itself with too many investigations at one time and thus has been compelled to depend for some of its deductions on an unduly limited range of evidence. Besides scientific deductions, it has the difficult task of deciding to what extent the phenomena and treatments in which it is interested, occur in or are applicable to, general commercial practice. In this matter also, really substantial evidence is essential.

192. The Bacteriological Branch has by its close contact with problems of manufacture and by its special resources, become very well fitted to assist in devising the two forms of experimental tea making machinery described in Section VI. We consider that it could, conjointly with the Chemical Branch, do very useful work in this direction.

The Value of the Work of the Scientific Department on Tea Quality and Manufacture.

193. We have explained in paragraphs 118 to 121 the way in which we set ourselves to answer whether results from research were likely to be commensurate with expenditure on it. On the side of tea growing we were able to point to improvements in the industry, from research, with which we were well satisfied. In progress made through research on tea quality and manufacture we find, superficially, less to satisfy us. But the difficulties here are far greater than in tea growing. Duly allowing for this and remembering the great industrial importance of manufacture, we are convinced that the money given up to research upon it, has been well spent. Even if no claim to specific improvement in tea making, as a result of research, could be made, a widespread awakening of interest throughout the planting community and in marketing circles, and a critical, enquiring spirit where formerly fixed and almost fatalistic beliefs prevailed, would themselves be substantial results. We strongly recommend a continuance of this side of the Association's research work, for we are convinced of its promise.

SECTION VIII.

ADVISORY WORK.

194. In Section I, we have adopted the view that it must be the purpose of the Scientific Department to employ the sciences for the economic betterment of the tea industry. This, we have explained, requires the Department to ascertain what are the major problems of the industry, and then to study the scientific questions which underlie these, keeping always in mind the purpose we have defined. To carry out this policy must involve the Department in three stages of activity. The first is to acquire new knowledge. This is research in its strict meaning and it constitutes the only basis for continuous progress in the industry. Secondly, is the development and utilisation of new and existing knowledge to a point at which it can be applied in growing leaf and making tea. It involves trials and applied experimentation. The third activity is the clear demonstration to planters of applications of knowledge arising from the second form of activity. It is what is commonly called advisory work. Discussion with witnesses who have given us their views impels us to call attention to the fact that no research organisation can help an industry unless it engages in all three of these activities and appropriately links them together as parts of a whole. And further, whether money for scientific work is plentiful or not, it is never sound to dispense with or disproportionately reduce any one of these three activities. Having shown the place of advisory work in a Scientific Department we proceed now to enunciate the principles by which it must be governed. This we do from a study of the special circumstances of tea in North-East India coupled with consideration of experience which has arisen from advisory work for crops and countries in general.

The Principles of Advisory Work.

195. We enunciate these principles thus :—

(*a*). Apart from the handing on of general experience and general scientific information, advice cannot continue to be given to an industry unless

new knowledge is obtained by suitable experimentation. We realise that this must appear upon reflection, to be obvious. But anxious desire for immediate advice may lead to error in this matter, as events in more than one country have shown.

(*b*). To be of substantial value to the crop producer, advice must apply to the circumstances of his own area. Therefore, although a central research station may obtain knowledge or expound principles of importance to many different localities, the application to practical industry must be worked out by special experiments in every locality. That is to say, local experiments as well as central research are indispensable.

(*c*). Such local experiments cannot be soundly devised or properly carried out in any locality save by an officer with an intimate knowledge of the circumstances of the locality. If the whole area served by the research station be large, resident local officers are essential.

(*d*). The proper demonstration and utilisation of experimental results, in any locality, as well as the carrying out of the experiments, requires intimate local knowledge.

(*e*). Although as explained in paragraph 194, research and advisory work are complementary, they cannot, save in special circumstances, be undertaken by the same group of officers. In the reasearch worker, highly specialised knowledge and a flair for investigation are essential. The advisory officer, on the other hand must, though scientifically minded, be distinguished by his interest in all practical sides of the industry. Further, limitations of time as well as of

interest and ability, ordinarily preclude the successful union, in one man, of research and advisory functions.

(*f*). Advisory officers, in close contact with their localities, are a very valuable means of keeping the central research station in touch with the problems and conditions of the industry, including their special local aspects.

(*g*). Notwithstanding what is said in (*e*) and (*f*), it is essential for the Director and his research officers to visit and keep in touch with all the localities served by the central research station. Only by so doing can they keep their researches properly directed towards the problems of the industry. And further, for special cases (*e.g.*, attack by a new insect) in which an advisory officer cannot provide information, the research officer concerned must act. It is, in fact, a function of every research officer to act also as a specialist advisory officer.

The Past Advisory Work of the Scientific Department.

196. Replies to our questionnaire brought many opinions, mainly strong, upon the advisory work which has been carried out from Tocklai. These are summarised in Appendix I (replies to Question II (*b*)). In discussion with witnesses we have been able to examine and give due weight to the various opinions expressed in writing. There is no doubt that planters as a whole are keenly desirous of more advisory help than they have in the past received. They are fully aware, also, that Tocklai could not possibly, with its present Staff, undertake adequate advisory work for the vast area it has to serve. We ourselves have judged the Scientific Department's advisory work both by opinions expressed to us and in the light of the principles enunciated in paragraph 195. We feel that we can both deliver judgment and at the same time draw inference for future use by saying that Tocklai has been deprived by limitation of Staff from carrying out adequate advisory work. This means that the planter has

not had the contact with scientific work which he desired and needs and that the special circumstances of each locality have not received due allowance in experimental work. Correspondingly, the research worker has had to run the risk of speaking from one place for all: and further, he has been compelled to undertake an unworkable combination of research and advisory duties.

Proposals for Local Resident Advisory Officers.

197. We are convinced that a system of local resident Advisory Officers is essential for the proper functioning of the Scientific Department. Proposals for such a system have been made more than once in the past. Our own detailed proposals are given in the passages which follow. By a study of the main tea districts and by prolonged discussion both with planters and with the Scientific Department, we are led to believe that the system we propose would prove both acceptable and practicable. It provides for an Advisory Officer, who would be a member of the Scientific Department, in each of the Districts shown in the table below:

District.	Members of I.T.A.		Non-Members.		Cess in annas per acre of tea for advisory work.	Place of residence of advisory officers.
	No. of estates.	Acres of tea.	No. of estates.	Acres of tea.		
Assam ...	325	249,493	286	45,600	2·8	1 on North Bank 2 on South Bank
Cachar and Sylhet ...	144	118,800	82	19,988	2·0	near Silchar
Darjeeling and Terai ...	73	42,814	65	22,126	5·6	near Kurseong
Dooars ...	105	103,185	50	28,799	2·3	near Nagrakatta

Advisory officers would, in all respects, including salary scale, be normal members of the Scientific Department. Each would have one or more subordinate assistants for outdoor experimental work. The annual cost of the system for each district which we provisionally take as Rs. 15,000 would be met by an

additional cess as shown in the table. This, being calculated to give the same total, differs in rate from district to district. It will be observed that the table makes no allowance for salary increments for the Advisory Officers. Moreover, no estimate of the cost of providing bungalows for them is made. These matters can, however, be dealt with by simple calculation if our proposals are accepted. In present circumstances there is no shortage of bungalows in some of the places named in the table. Every Advisory Officer's duties would include, as we explain below, the making of field-scale experiments. We have considered with great care whether such experiments could be carried out on estates or whether local sub-stations would be necessary. Our conclusion is that experiments could be made on selected estates, the estate providing land, labour, and materials, and the Advisory Officer with his subordinates, taking complete charge. We are well aware that in some territories "estate experiments" have been adjudged a failure because the farmer, the planter, the cultivator, the peasant or whoever is concerned, cannot or will not, fully play his part. But we know also that in other territories such experiments are a normal part of the activities of research stations and a most valuable means of practical progress. Our thorough inquiries have left us assured that the planting community in every district of North-East India, given the opportunity, would ensure the success of a system of local experiments under resident Advisory Officers. We therefore earnestly hope that owning companies and agency houses as a whole would give both formal sanction and also encouragement to experiments on estates. Our next step is to state in detail the duties we consider proper for a resident Advisory Officer.

The Duties of a Resident Advisory Officer.

198. Every resident advisory officer should be a member of the Scientific Department, and have the following duties:

(*a*). To learn intimately all the circumstances of his locality which affect the tea industry. This would involve among other things the making of

certain surveys with the construction of maps showing their results, e.g., surveys of soil type, of disease distribution, of tea jats, of seed supply, etc., as described in Sections III and VI.

(*b*). To carry out field experiments on estates in his locality. The nature of these experiments would be decided by the Director of the Scientific Department, in conference with the Advisory Officer, who would naturally take into full account the needs and circumstances of his locality and the views of its planters.

(*c*). To give advice to tea gardens in various appropriate ways including: visits to gardens upon request; demonstrations on his experimental plots; occasional lectures. This advice would not be rigidly restricted to tea but might well include supply of shade-tree seed and even matters affecting rice cultivation or cattle. In cases of special difficulty, the help of the appropriate specialist officer at Tocklai would have to be arranged.

(*d*). To keep the Scientific Department in close, constant touch with the events, circumstances, problems and opinions of the tea industry in his locality.

(*e*). To make experiments and enquiries for the research officers at Tocklai with the approval of the Director.

(*f*). Generally, to do everything possible to foster the interests of the tea industry in his locality.

(*g*). To work under the orders of the Officer at Tocklai in charge of agricultural experiments whose duty it should be, subject to the authority of the Director, to develop the advisory service as fully

as possible. A resident Advisory Officer should correspond directly with planters and others in his locality, but should keep his superior at Tocklai properly informed of important communications and proceedings.

Qualifications of a Resident Advisory Officer.

199. We have been at pains to satisfy ourselves as to the type of man desirable for the post of resident (local) Advisory Officer. Our planter witnesses have shown unanimity on this question and their views conform closely with what is to be learned from agricultural advisory services in general, both at home and in the varying types of British tropical territories. The qualifications and training which seem to us desirable are :—

(*a*). A keen interest in practical agriculture and all that pertains to it. A farmer's son might be well fitted in this respect but represents by no means the only eligible type.

(*b*). A University honours training in pure science; or a University Degree in Agriculture followed by post-graduate training in field experimentation on modern lines. Of the two qualifications we should, in general, prefer the honours degree.

(*c*). In the case of an honours science graduate, a subsequent training in agriculture and the applications of the sciences to agriculture together with a training in field experimentation.

(*d*). A short period—about one or two months—in London with tea brokers and agency houses.

(*e*). Six months on a good tea estate in North-East India in which period he should work exactly as if he were a newly appointed Assistant.

(*f*). Six months at Tocklai.

It may be objected that the home training we suggest is inordinately long. Our reply would be that we suggest no more than is now found necessary in analogous cases. Or it may be held that financial considerations would deter young graduates from embarking on the long training suggested for these appointments. To this we answer that it would be a thoroughly sound investment for the industry to follow the example of the Colonial Office and of the cotton industry in giving scholarships to young graduates selected to fill vacancies.

Relations with Agency Houses and Private Advisory Officers.

200. We have considered, with the help of witnesses, whether the role proposed for resident Advisory Officers would be in any way incompatible with the part played by Visiting Agents or by the private Advisory Officers employed by certain companies. In our view there is no ground for uneasiness here. The resident Advisory Officer can do no more on an estate than offer advice when asked for it. Working policy and executive action on estates would naturally remain with those who now have the control and it would be for them to decide, how, if at all, to use the Advisory Officers' information.

201. The system of Advisory Officers constitutes, in our view, the Scientific Department's outstanding requirement. These officers, besides providing an urgently needed advisory service, would give to the Department's researches that widespread testing for lack of which they have been severely and inevitably criticised. Before leaving the subject of advisory work we must take up two matters closely related to it. These are : publications and lecture courses.

Scientific Department's Publications: The "Quarterly Journal".

202. An institution with duties like those of the Scientific Department must issue two kinds of publication. The results of its researches must be given in scientific form : and secondly, the applications of its results to the practices of the industry must be stated in brief, clear, practical form. To confuse or to

try to unite these two ways of describing the outcome of the work of a scientific department has over and again proved wrong. In Section X we deal fully with the question of scientific publications. For the publication of practical results and for a general written medium for advisory work, four principal suggestions have been carefully discussed with our witnesses. These, with our own conclusions concerning them are :—

(*a*). That the *Quarterly Journal* should resume publication. The main reason given in support of this is the desire of the average planter to be informed, not less than about four times a year, of the work proceeding at Tocklai and of its results. This is robbed of its force, we feel—and most of our witnesses entirely agree—by the proposal for resident Advisory Officers. Against the *Quarterly Journal* some strong reasons have been given. Scientific investigators it is urged (by planters), should not be asked to spend their time in producing non-scientific articles with a regularity that makes them hack-writers. And, further, since scientific results do not accrue with quarterly regularity, the *Quarterly Journal* is likely to need—and did in fact formerly show—a considerable amount of padding and repetition. We are against the restoration of the *Quarterly Journal*.

(*b*). That the Scientific Department should publish an Encyclopaedia or Handbook on Tea. What supporters of this idea desire is a small reference volume which they may consult on matters such as the names, seed rates and methods of using of shade trees : the percentage of nitrogen, etc., in various fertilisers; spraying formulae and so on. A Handbook of Information of Tea was issued by the Department in 1929. We think it would be wise to defer a new publication of the handbook kind until the pamphlet system (*c.f.* (*c*)

below) has been fully developed and until by means of the experiences of the proposed Advisory Officers, the needs of planters have been closely ascertained.

(*c*). That Occasional Pamphlets should be issued from time to time as practical applications of research work arise or matters of interest develop to a stage at which they may be reviewed with safety and with profit. This proposal we consider good. Several occasional pamphlets or bulletins have, of course, been issued by the Department, but their form has not, we are assured, been wholly suited to the readers' desire. Criticism, which we have carefully examined, may be simply summarised. It is held that past publications of this kind have been in the form of an account of experiments, with a considerable amount of numerical data. They have described general principles and relationships instead of giving clear recommendations for practical action. In short they have been popular paraphases of scientific papers rather than practical instruction. The difficulty of uniting brevity and precision with necessary caution and reservation is well-known in writing on agricultural topics. We feel, however, that unremitting effort should be made to produce pamphlets free from the objections stated above. Some of the British Ministry of Agriculture Leaflets, we suggest, might be taken as typical of what is needed. Attention to publishing detail would be well repaid as, for instance, in a common format; an index, and arrangements (through a binder) for binding or filing.

(*d*). That the present Annual Report (with which we deal fully in Section X) should be displaced by an entirely new form of Annual Report for

planters. This should be brief and in non-scientific language. It should clearly explain the purpose of the investigations of the past year, their general nature and where appropriate, the trend of the results. Details of plot layout and of experimental data should not be given. Short articles of current general interest, as distinct from a review of current research, might be added. Certain other similarly circumstanced Scientific Departments issue Annual Reports which are considered to be of the kind here contemplated. We think this new form of Annual Report should be adopted.

203. In Section XI we briefly refer to the possibility of an inter-country scientific periodical for tea research. Whether, correspondingly, a non-technical journal could be produced by countries collaborating in research is a question to which, we think, attention should be given at some later date.

Lecture Courses at Tocklai.

204. The number of Tocklai lecture courses for planters was reduced we understand, as an inevitable result of staff changes made during the recent financial crisis. Our witnesses of all kinds have expressed nothing but regret at this reduction. Some of them complain that the courses cover too much ground and would be more helpful if their field were limited to tea growing and tea making in alternate courses. Another criticism is that lectures occupy undue time to the detriment of practical demonstrations. But these criticisms, made in very good-natured terms, are trifling in comparison with the appreciations, warm and everywhere repeated, of the value of the courses. The opportunity to attend is much smaller than the desire and we strongly recommend the immediate restoration of the full number of courses.

The Training of Planters.

205. It would be illogical to examine the question of advisory work without considering the planting community itself.

In Europe, in America, and in tropical countries, it has become very clearly recognised that advisory service to crop producers is not an isolated agency of progress but a part of the great undertaking of agricultural education. We feel that our terms of reference prevent us from making specific proposals but we respectfully and most strongly urge upon the tea industry of North-East India the importance of considering the recruitment and training of planters in the light of current developments in home and tropical agriculture.

The Attitude of the Planting Community Towards the Scientific Department.

206. In our questionnaire we invited the planting community to offer frank criticisms of the work of the Scientific Department. As may be seen from Appendix I the planters' criticism was conjoined with appreciation and our many discussions have convinced us that the general attitude to Tocklai is healthy. We are nevertheless constrained to call attention to the importance of this attitude. It may be said in part to govern and in part to reflect the effectiveness of scientific work on tea. The ultimate purpose and the ultimate interest of scientist and planter are one and it is to be hoped that an active consciousness of this will continually inspire both of them. We have, here, one suggestion to make, *viz.*, that regularly, once a year, a selected body of planters' representatives should pay a visit to Tocklai. We suggest that these representatives, one from each District, should be nominated by their District Associations, from the most senior and influential members of the local community. Men of this status naturally do not attend courses of instruction. Some occasionally pay private visits to Tocklai but great advantage would accrue from a combined visit. Two purposes would be served. The Scientific Department would be able to discuss the field of their research with an exceptionally well equipped body of advisers : and for each District, an accredited representative would each year be able to take back first hand impressions of the efforts being made to assist the tea industry by scientific investigation. In the past, particularly since the

Tocklai Staff was reduced, the planting community has felt itself outside the effective reach of its Research Station. While it is patently the duty of the Station to keep itself in touch with the problems of the industry it is no less patently incumbent on the industry to inform itself constantly of the aims and work of its own station. Visiting agents, or Directors coming out from home, could play a highly important part by occasionally going to Tocklai. The past infrequency of their visits has, in our view, been proof of a regrettable lack of interest.

SECTION IX.

THE TOCKLAI STATION.

207. In reporting on the Station we deal successively with :

Land.

Laboratories and Equipment.

Factory.

The numerical strength of the Staff of the Scientific Department comes under discussion in Sections IV and VII. Criticisms and suggestions concerning land and factory have flowed freely into us both at home and in India. We have encouraged our witnesses to speak at length on matters affecting the Station itself, not only for our own information, but in the hope of helping to promote an understanding, vitally important both to science and practice, of the relationship between experimentation and the practical use of its results.

Land.

208. The Station's land consists of 30 acres at Tocklai, 30 acres at Tulsipara (320 miles away) and about 140 (plantable) acres at Borbhetta (2½ miles away and easily reached) of which some 73 acres are planted. The small area at Tocklai itself is occupied by Staff houses, laboratories, factory, and other buildings and in addition provides space for the small plots of tea which it is essential to have immediately next to the laboratories. There is no need for any great expanse of land at Tocklai (the main plots being at Borbhetta) but we recommend that in the near future a plan of development be drawn up for the land in possession there in order that any future buildings on it or uses of it may be wisely arranged. On general grounds of geography, and of society, Tocklai is a good centre for tea research.

209. Borbhetta has been doubly criticised. In some reports on experiments the patchiness of its soil has been said to make precision unusually difficult. The remarkable uniformity of

many vast stretches of land occupied by tea in parts of North-East India may well show up irregularities at Borbhetta but it cannot be doubted that the soil there is quite well suited in point of uniformity, to experimentation. From a number of planter witnesses has come the second criticism that Tocklai and Borbhetta soil and climate are exceptional and so cannot represent the conditions of any but a trivial fraction of the tea estates. We kept this criticism in mind when going round the tea districts. Certainly no single place could be taken as representing North-East Indian tea as a whole either in soil or climate. But Tocklai and Borbhetta do represent as considerable an area of tea land as could be expected of any single place. Moreover, in so far as such conceptions can be formed, the modes of soil, climate, and other circumstances seem to be found at any rate reasonably well in the Tocklai neighbourhood. The 60 acres remaining unplanted at Borbhetta should suffice for the visible future land requirements of headquarters experiments

Local Sub-Stations.

210. It would be a very obvious advantage if a permanent sub-station could be maintained in each of the main tea districts. Suggestions for this have come from several witnesses, especially in certain of the districts. We have had to set the idea aside as financially impracticable but we feel sure the system we have proposed (in Section VIII) will supply the basically necessary local experiments. Tulsipara, the only existing out-station, involves very modest upkeep and, because of the usefulness of the experiments carried out there, should, we consider, be carried on.

The Use of Small Plots.

211. We have found in some written replies sent to us and in some discussions, a mistrust, occasionally openly expressed, of results from experiments in which use is made of small plots, *i.e.*, of the order of a tenth of an acre. It has been held that these cannot allow for all the circumstances of commercial-scale tea growing. The allegation is true: for certain points, especially

concerning labour requirements, cannot be brought out except in large-scale working. But this does not mean that small-scale experiments can produce no results of value to commercial tea growing. On the contrary, we are convinced that in the main the use of plot experiments by the Scientific Department is correct and efficient and in conformity with the ideas universally prevalent in all forms of agriculture. It is, however, relevant at this point to make the important criticism that in deducing practical applications from plot experiment results, the Department has in some cases argued as if all its circumstances were exactly the same as those on tea estates. The strong practical interest of the proposed Advisory Officers may be expected to provide the Department with its own, locally informed critics, in matters of this kind.

Laboratories and Equipment.

212. We consider the Station is well off in laboratory buildings. Some additions to chemical and other equipment are desired but these are such as can be dealt with through the annual estimates. The laboratory-scale tea-manufacturing plant of which we speak in paragraph 158 and again in paragraph 230 (*a*) can also be financed by the annual expenditure of the next few years. We here record our view that it should be treated as essential for manufacture studies. Only one other question arises here and that is the Library. Additional books are necessary and could be provided from annual expenditure but there is no space to store them. An extension of the library building with the necessary shelving, would cost about Rs. 2,500 to Rs. 3,000 but we think it practicable to supply what is required and at less cost by re-shelving and re-lighting the existing space.

Factory Experiments.

213. The factory at Tocklai has equal place with the Advisory System as a subject of complaint, and of comment, developing at times into witticism. Our own views about factory requirements are naturally derived from the policy of investiga-

tion on tea quality and manufacture which is set out in Sections V and VI. We consider the following are necessary :

(*a*). The building up of a very small laboratory-scale tea-making plant for experiments on the quantities of leaf obtainable from even single bushes.

(*b*). The improvement of the present factory so as to make it meet all the requirements of plot work (*e.g.*, manuring or plucking experiments) and certain initial requirements of the study of manufacturing processes. Its present size (the roller-charge being 20 to 50 lbs.) is appropriate for these purposes.

(*c*). The creation, in the light of experiments including those of (*a*) and (*b*) above, of a manufacturing plant of about the same capacity as the present one, but specially suited to experimental work. The scope and purposes of this have been explained already in paragraphs 163-4. This undertaking should proceed as soon as the requisite knowledge is available. The machinery might be housed with that of (*b*) in an extension of the existing building or a new building of about the size of the present one might be necessary.

(*d*). A system for using suitable and available commercial factories for large-scale test of methods devised in small-scale experiments. This is explained in paragraph 246.

It is, as already explained, by our study of the field of research on quality and manufacture that we have been led to this policy for factory equipment and large-scale work. We have devoted great care to the present situation and to alternative policies and we think it well to treat of these somewhat fully.

The Present Factory.

214. The present factory suffices to perform in an admittedly imperfect manner, the tea making connected with plot experiments. It is not equipped for any but the most limited experiments on manufacturing processes. We do not speak of responsibility for this state of affairs, which merely reflects the state of development reached in quality investigations and is not in any way the out-come of the financial policy of the Scientific Department Sub-Committee. Many strong criticisms of the factory and its working have been made but all of them imply, directly or indirectly, that the Scientific Department should make its tea in a factory of normal, commercial size.

The Need for a Full-Size Factory.

215. Many sections of the planting community have put forward, as a principle, that nothing of value for commercial work can be learned except in a big factory. Our reply is that there are principles common to tea making in factories of every size and that it is these principles which the Scientific Department should labour to discover as a basis for improved methods in large-scale practice. The extremely interesting discussions we had on this point in the various tea districts showed that planters as a whole quickly saw and admitted these arguments. Our experience leads us to say that we think the Scientific Department has suffered unjustly and unnecessarily in public opinion by not making more clearly and widely known its policy in experimentation on manufacture and the inevitable limitations of scale that have to be faced.

216. Brokers have also been critics of small-scale tea making and we have fully ascertained their views. We conclude, after most careful study, that neither the brokers' criticism nor the planters' constitutes a sound reason for equipping Tocklai with a large factory.

217. Certain other arguments have been put forward for a large factory. One is that the Scientific Department would

carry far more weight in the industry if it were to show that it had the ability to grow leaf and make tea on a commercial scale and at a profit. The analogous idea comes up, of course, in connection with every research and teaching centre in agriculture. Much can be said in favour of it; and much against. Men giving their minds to scientific research cannot ordinarily at the same time, even if they possess them, exercise those faculties of business which, just as much as technical knowledge, are required in practical planting or farming. Moreover, a research station might show a profit on practical planting by enlisting a highly competent manager from some other garden and giving him his freedom. It would not thereby be showing the great practical ability of its scientific staff. Moverover, it is very easy to water down the success of a scientific station in practical crop production by allegations of peculiarly favourable conditions. The fact is that for an agricultural scientific centre, especially one for teaching as well as research, to achieve success in practical production, is an immense asset. But unquestionable success is not easy to achieve without sacrifice of the interests of science; and limited success, or failure, is a great handicap. Every research centre must solve this problem in the light of its own special circumstances. Our conviction is that the argument of status in the eyes of the planting community does not justify a large-scale factory at Tocklai.

218. Some planter representatives have argued, further, that by running a big factory and garden the Scientific Department would be kept in very close touch with practical conditions. For the reason given in paragraph 217 we do not think this necessarily holds. Moreover, any scientist anxious for practical contacts would be a welcome visitor and have unfettered liberty for observation in most factories.

The Objections to a Large Factory at Tocklai.

219. We have in paragraphs 217 and 218 given our reply to arguments widely used in favour of a large factory at Tocklai.

To these we now add the following specific objections :—

(*a*). A factory, to be used for experiments, must be capable of rapid and great alterations. If, for instance, it were desired to find out the effect of withering leaf to 65% moisture in periods of time from 24 down to 4 hours, no ordinary commercial factory could be used. To equip a big factory with machinery capable of the great variations required for far reaching experiments would be exceedingly expensive both initially and in running. That is to say, for making actual experiments and trying entirely new methods as distinct from straightforward tests, only a small-scale factory can be used.

(*b*). For experimental plots, separate amounts, each of about 20 lbs. of green leaf, commonly have to be manufactured. For this a large factory is obviously useless.

(*c*). Results obtained in a large factory at Tocklai would be unacceptable in other areas, as Tocklai results are now, because of differences in conditions. Thus the demand for a large factory for experiments is really a demand for several.

(*d*). Ignoring (*a*) and (*c*) above and thinking only of one normal, large, factory for the Scientific Department, cost is a great obstacle. A factory is useless without leaf and to acquire the necessary acreage of land securely and permanently would, we feel, lock up money better spent on other well proved needs of the Department.

We have repeatedly asked ourselves and our witnesses in precisely what ways a large factory at Tocklai would be used to advance knowledge of quality and manufacture. The conclusion we reach is that for the present the idea of such a factory should be abandoned.

Our Recommendation as to a Factory.

220. Our recommendation is that funds be supplied as required for the experimental factory developments set out in paragraph 213 (*a*) to (*d*). We do not attempt to estimate costs, which will be spread over several years. Stage (*c*) will have to wait on progress and experience in (*a*) and (*b*). When entered upon, it will involve building unique machinery, *i.e.*, every piece specially built to the Scientific Department's own design. Success in both designing and construction will naturally depend very much on the attitude taken by makers of machinery. That their own interest may be affected by the progress of experiments with the new machines is a consideration which the tea industry should be at pains to expound.

SECTION X.

THE ORGANISATION AND CONTROL OF THE WORK OF THE SCIENTIFIC DEPARTMENT.

221. We have, in Section I, enunciated principles in the light of which we took up our terms of reference. One of these is that the constitution and administration of any research station should be primarily designed to promote the scientific work of the station and should, therefore, subserve it. It is by this principle we are guided in the present Section which deals with the following matters :—

Deciding which problems of industry shall be studied.

Planning experiments to deal with these problems.

Carrying out the experiments.

Staff matters.

Extension of experiments to the various tea districts of North-East India.

With the Advisory work of the Department we have already dealt in Section VIII.

222. The first step in planning the work of a scientific department, lies in deciding which problems of the industry shall be studied. Resources never allow more than a limited proportion of the problems to be dealt with at any one time; some problems affect only a small area; some are ephemeral, arising from the special circumstances of a particular season. To make choice of the problems thus requires a wide knowledge derived from close touch with the industry. It is clearly insufficient to choose a list of problems on the basis of their industrial importance. They must be formulated in such a manner as to facilitate their handling by scientific methods. For this, wide scientific knowledge is necessary. Now only the Chief Scientific Officer in an industry is able to combine scientific attainments with an intimate knowledge of the industry and thus the choice of problems for study must be made by him. How he can most effectively keep in touch with the circumstances and problems of the indus-